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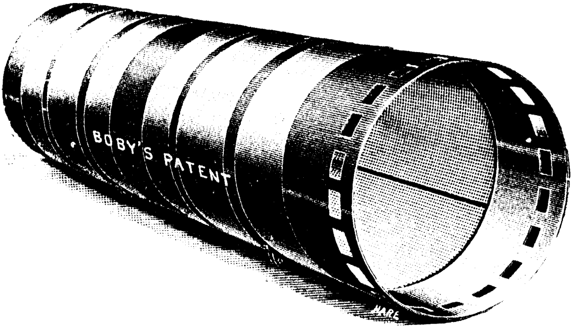

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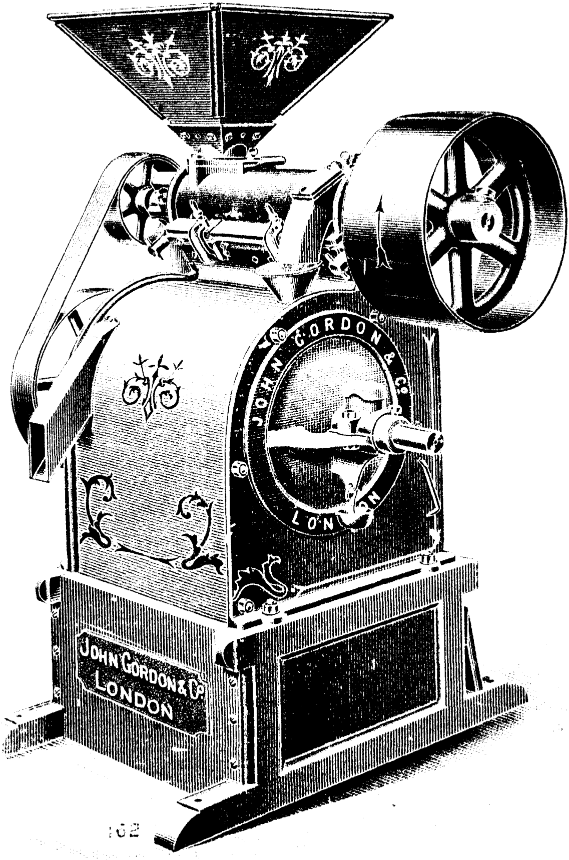

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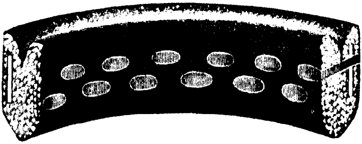

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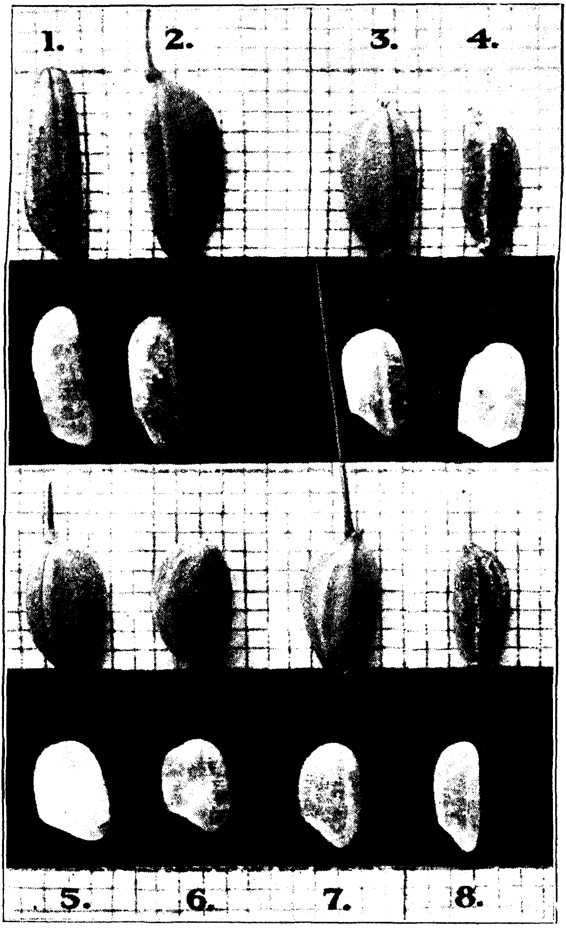

EIGHT VARIETIES OF RICE

The top and the third rows are Paddy, the second and the fourth are shelled Rice. The varieties are: 1. Seeta (India); 2. Uganda; 3. Lower Burma; 4. Java; 5. Egyptian; 6. Spanish; 7. Manchuria; 8. Upper Burma.

Frontispiece

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RICE

ITS CULTIVATION AND PREPARATION

BY

CHARLES E. DOUGLAS
M.I.MECH.E.

MEMBER OF COUNCIL OF THE BRITISH ENGINEERS'
ASSOCIATION, ETC.

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PREFACE

THIS is perhaps the first attempt to put together a consecutive review of the subject, the title of this little book. There is a great deal of most valuable information published in many books, reviews, bulletins, and reports on different aspects of the matter, the result of observation and experiment in many lands. As the author proceeded with the preparation of his notes it almost seemed as though he had undertaken to do the impossible, in attempting to deal with the subject within the limits of such a handbook.

The inevitable result is that many references and much interesting information have had to be cut down or entirely omitted.

A note of some interesting books and reviews, together with sundry tables bearing on the subject, will be found in the Appendix.

The author takes this opportunity to acknowledge, with grateful appreciation, such information as he has obtained from some of the publications referred to above, from some of the learned Societies and Institutes, and from kind friends.

He also desires to express his thanks to Messrs. John Fowler (Leeds), Ltd.; Messrs. Robert Boby, Ltd.; Messrs. W. T. Avery, Ltd.; and to Mr. R. H. Brown and others, for permission to reproduce blocks kindly lent by them.

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THE CULTIVATION AND PREPARATION OF RICE

CHAPTER I

HISTORICAL

In the far-off days of primitive man, we can conceive that the practice of agriculture, however rudimentary, must have been one of his principal occupations. Warfare with his fellow men occupied, no doubt, a considerable proportion of his energies ; warfare—whether for safety or for food—against the inhabitants of jungle and forest, bred the hunter ; but the cultivation of the fruits of the earth must have absorbed such time as was not occupied in these less pacific pursuits.

The selection of edible vegetation was no doubt fraught with many interesting experiences until the primitive man learned what he and his people might eat with impunity. Having made his selection on broad lines he would be faced with the problem of securing a reasonably continuous or recurring supply. This, no doubt, would again involve considerable periods of trial and error until the mystery, and the reasonable certainty—under certain conditions—of seed-time and harvest would be borne in on his mind.

The rudiments of agriculture would thus be established : seasonal influences would be recognized ; and with these there is little doubt—judging from the evidence in our possession to-day—that some form of religious observance gradually took shape—some recognition of the recurrent phenomena which resulted in the all-important matter of food.

We know of the worship of *Demeter*, the earth-mother, by the Greeks, and of the later worship of the goddess *Ceres* by the Romans—that goddess to whom mortals were bound to return thanks for the kindly fruits of the earth, and from whose name is derived the term applied to certain crops universally known as cereals.

The principal cereals are wheat, barley, oats, rice, millet, maize, and one or two other similar plants. Of these, wheat is no doubt by far the most important as far as the white races of the world are concerned. Rice, however, plays an even more important part, being, as it is, the principal food of more than half the inhabitants of the world. Of the antiquity of wheat cultivation in Europe we have clear evidence in the remains of the lake dwellings of Switzerland, but in respect of rice our records are not so definite. Neither in the Bible nor in the tombs or writings of ancient Egypt or Persia do we find any reference to rice. It is stated that the wonderful gold effigy of Tutankhamen, recently discovered within its protecting shrines, shows that sovereign to be holding a sceptre in one hand and a flail in the other—a tribute to the might of agriculture in his day; but the introduction of rice—a valuable crop in Egypt to-day—was probably effected at a much later period.

It is recorded that the sowing of rice was an important religious ceremonial in China nearly 5,000 years ago: records to that effect are clearly enough established. To the Emperor alone is said to have been reserved the privilege of sowing rice, the less important cereals being reserved for less exalted members of his family.

This is the oldest record of rice cultivation which we possess: Theophrastus, the "Divine Speaker," born some 375 years B.C., who studied under Plato and Aristotle, refers to the cultivation of rice as an established branch of agriculture in India. Reference is made also in the Talmud, at a later period, to the cultivation of this cereal.

We are safe in assuming, therefore, that we are dealing with one of the earliest important cereal foods when writing of rice : its importance as an agreeable, easily digested, and cheap food has in no wise diminished since the time—doubtless to be reckoned in thousands of years—when its regular cultivation first gave employment to man.

While dealing with this aspect of our subject it may be of interest to recount some instances of rites and ceremonies connected with the cultivation of this particular grain.

Mention has already been made of the Imperial planting of rice in China, a religious ceremony of the first importance. Even more interesting, perhaps, is the instance recorded by a traveller in Borneo who observed no fewer than six distinct religious rites in connection with one crop—rites of thanksgiving as, one after another, the various stages of cultivation, harvesting, and storing were safely accomplished.

In the island of Java, rice is considered as the offspring of the goddess Dewie Srie, and on the occasion of a certain autumn festival the worshippers follow up the Mohammedan Bismillah by a seven-fold repetition of that Goddess' name.

The Javanese—and this is the case among many other native races—consider the choice of an auspicious day for commencing their agricultural operations as of far greater importance than careful tillage ; not only the day but the very hour is the object of special attention ; even the method adopted in ploughing has to be selected appropriately and accompanied by suitable prayers and sacrifices.

In Persia, harvesting operations must not commence on a Wednesday, nor yet on the thirteenth day of a month—an interesting instance of the time-honoured superstition attaching to that number.

In certain parts of India, we find rice entering into ceremonial observances. For instance, part of the marriage rite consists in the priest scattering powdered rice over the bride and bridegroom, doubtless in the belief that by doing so the worldly prosperity of the happy couple is assured.

Perhaps this interesting ceremony was the origin of the custom which has persisted to our own times, and has given so much enjoyment to the assistants and caused so much embarrassment to the principals at our own wedding celebrations.

A more agreeable modification of the same idea is that still prevalent in Japan. As recently as in the month of January, 1924, when the Prince Regent was married, and after the Imperial couple had reached the palace which was to be their future home, a grand fête took place, terminating with the presentation of rice cakes which symbolize long life, happiness, and abundance during the years to come.

Among certain Hindu people it was customary to make an offering of rice on the birth of a male child.

The Sanskrit name for rice is "Dhánga," which means the "supporter (or nourisher) of mankind," and no doubt the significance of this would be present to the mind of the donor as well as to that of the proud father.

One more instance only; on a certain Thursday following the harvesting of a rice crop, it was customary to take a grain measure, to fill it with new grain, and to add pieces of gold, silver, and other coins, after which the measure was worshipped in honour of the Goddess of Fortune. This ceremony over, the measure, still containing the grain and the coins, was placed in a clean earthenware vessel, and carefully preserved until the corresponding day of the next Hindu month ; when it was again brought forth for worship, and so on during each succeeding month until the next harvest, when a new measure would be selected, similarly filled, and treated as an object of reverence.

At a recent exhibition of agricultural machinery in Southern India, the author observed a number of machines, intended for milling rice, covered with written prayers, invoking the blessing of the appropriate deity on the machinery and on the functions which it would be called on to fulfil.

Many other instances of rites and ceremonies could be referred to, but those cited are sufficient to indicate the importance of the crop in the lives of the people. To them, a good harvest means food and life, while a bad harvest spells famine with all its attendant horrors.

Under such conditions, the need of wise agricultural methods to take the place of superstitious ceremonies becomes increasingly evident.

CHAPTER II

BOTANICAL AND PHYSICAL CHARACTERISTICS

RICE is a member of the great family of grasses to which belong the familiar home-grown cereals, wheat, barley, and oats.

The botanical name is *Oryza*, which is, in fact, the original Greek name. It may be interesting to compare this with the old vernacular Telegu name *Uri*, as well as with the Tamil word *Arisi*, although the latter is used to denote rice after removal of the husk. This name is preserved to us to this day in the Spanish and Portuguese languages, in which the word for rice is *Arroz*. No doubt this name was introduced into the Peninsula by the Moors, who overran that part of Europe for several centuries.

Although there are several members of the *Oryza* family, that with which we are concerned is *Oryza Sativa*, the ordinary rice of commerce.

The plant is almost certainly indigenous to Asia, and most probably so to the south-eastern portion thereof, though whether India or China is the original home is a matter of doubt.

The cultivation of the plant spread westward from India to Persia and Egypt, and by degrees, along most of the European and a portion of the African littoral of the Mediterranean.

As the seed was passed on, accidentally or by design, from one country to another, and became influenced by new conditions of soil and climate, as well as by human intervention, its cultivation also became varied, until the differences in grain characteristics began to assume bewildering proportions.

To the ordinary reader, it may come as a surprise to learn that there are at least 5,000 known varieties of rice. In India alone there are said to be over 1,100, while the American Bureau of Agriculture classified as distinct varieties 990 out of 1,280 samples tested and examined by that Department.

Even the miller, who is responsible for converting the raw rice in the husk into the finished white rice of commerce, does not usually include in his purview more than a score or two of varieties. He may tell you that he prefers to mill a sturdy variety like Japan rice, rather than some of the long, thin grains grown in parts of India, Siam, or the Philippines, for the simple reason that the one " mills " better and is susceptible of less breakage than the other ; beyond that, he is really not greatly interested.

The extraordinary number of recognized varieties which do occur is not easily understood ; rice is said not to cross so easily as many other plants, so that one is led to examine other conditions as being the governing factors in the production of varieties possessing characteristics sufficiently marked to permit of such a wide range of classification.

Without going into a detailed description of different varieties, which has already been done much more fully than is possible here, the reader will be able to observe, from the illustrations accompanying this text, some typical varieties collected from different parts of the world, which will show some at least of the more pronounced physical characteristics of various grains.[1]

Cultivated rice is an annual which quite frequently attains a height of from 5 ft. to 6 ft., although there is a variety, known as " giant rice," which attains a height of as much as 12 ft. to 15 ft.

[1] See *Frontispiece*

The leaves are long and tapering, from 12 in. to 24 in. in length by as much as 1 in. in width at the broadest part in the more fully grown varieties.

The flowers appear as single-flowered spikelets, in what are termed panicles, from 8 in. to 12 in. in length ; the panicles are upright immediately on formation, but as the grain ripens they assume a graceful arched form. The pales are persistent, and form the husk of the ripe grain. In some forms to which frequent reference is necessary, the lower pale carries an awn or beard, sometimes of considerable length. The pales or husk enclose but do not adhere closely to the true grain or kernel inside.

Various methods of classification have been attempted, but, owing to the almost bewildering number of varieties, such classifications can be determined only by the expert botanist, and do not concern us closely : one variety merges imperceptibly into another, but these variations are not for us to consider in such a brief general review.

Roughly speaking, however, rices are divided according to habits of growth and cultural requirements, as well as according to clearly defined grain characteristics.

A common primary classification consists in differentiating lowland, aquatic, or transplanted varieties from upland or true hill rice which, sown broadcast, is not usually transplanted as most Oriental rices are.

Each of these is further sub-divided according to whether it includes an early, medium, or late variety, as well as according to height of growth and to the presence or absence of the awn or beard.

Coming to classification according to grain, we have two main varieties, non-glutinous and glutinous rices, the former being the true *Oryza Sativa*, while the latter is known as *Oryza Glutinosa*. Glutinous rice does not contain so much starch as the more common variety and, when cooked, it is of a sticky consistency, causing the grains to cohere.

These two main varieties are further sub-divided according to length, girth, and colour—long grained and short grained, large, medium, and small grained, and common coloured or specially coloured.

We have mentioned that there is a great difference in the length of grains, many varieties being twice as long as others, even when the latter are fully grown. A glance at Patna and Japan rice grains, placed side by side, shows this difference at once, the former being a long, relatively thin, and more or less cylindrical grain, the latter being short, broad, and rather fat. (See *Frontispiece.*)

While the majority of rices exhibit husk of golden colour, this is by no means universal, and the tint of certain varieties is somewhat purple in its general effect.

For reasons which we shall discuss later the bearded varieties are not willingly cultivated ; similarly, those exhibiting a red skin or cuticle under the husk are preferably excluded as far as European and American markets are concerned.

Without attempting to go any more deeply into this somewhat involved matter of classification, we must, at least, consider the distinctive characteristics common to all rice grains. These are four in number and may be summarized as follows—

1. **The Outer Husk,** usually golden in colour, although, in certain cases, deep purple-tinted or almost black. This, as we have seen, is formed from the pales of the plant and consists of flattened dried cells.

2. **The Cuticle or Inner Skin,** which varies in colour from a creamy white to a deep mahogany red, and consists of cells containing gluten or nitrogenous matter.

3. **The Kernel,** or actual rice grain as used in its

highly milled state for food, and consisting almost entirely of minute starch cells.

4. **The Germ,** which, while it appears in a grain of rice after removal of the outer husk and before milling, is not visible in the ordinary milled white rice of commerce, as it is removed in the processes through which the grains pass in the course of preparation for market. The cavity, or nick, in which the germ has lain is clearly noticeable at one end of any whole grain of rice picked out of an ordinary shop sample. (*See* Fig. 1.)

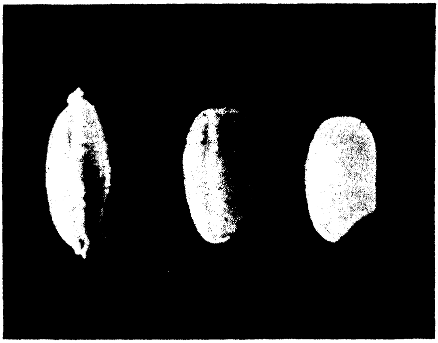
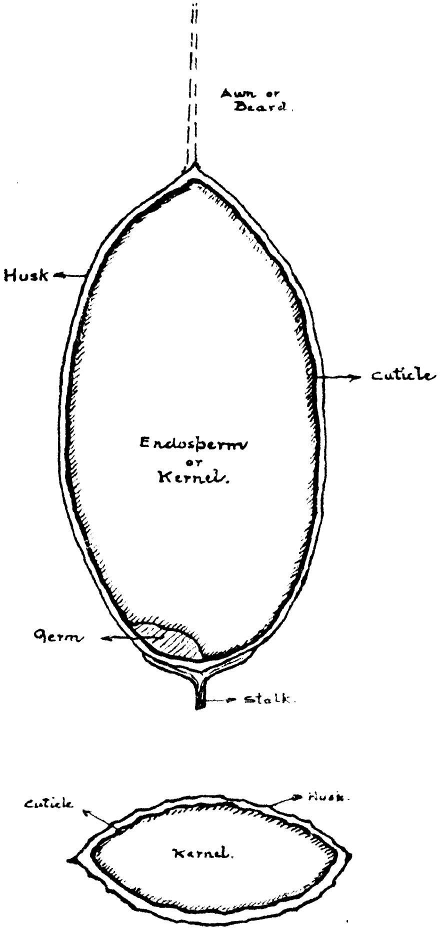


FIG. 1

SPANISH-JAPAN RICE GRAINS

In the husk, husked, polished

We have seen that certain varieties possess a fifth physical characteristic which is not, however, common to all grains, as are the above-mentioned four features ; we refer to the awn or beard which is attached to one of the pales or half-coverings constituting the husk. This is a long spike projecting from the grain at the



ENLARGED SECTION OF A RICE GRAIN.

FIG. 2

end opposite to that at which it is attached to the stem. This spike or beard is often twice, and may be four or more times, as long as the actual grain itself. Bearded varieties are undesirable from the point of view of the cultivator as well as of the miller ; in the first case, because their yield is not so good as that of the unbearded varieties ; and, in the second case, because it is often a matter of real difficulty to remove the beard, which is of a tough, wiry nature. Even the threshing process, which removes the grain from the straw, fails in many cases to break the awn or beard away from the grain. It is then necessary to pass it, after threshing, through special awning machines before it is possible to subject it to the usual milling processes.

In addition to the handicap imposed by this objectionable feature, the possession by certain varieties of a red cuticle is much against them. The cuticle or skin lying immediately under the husk, and appearing as soon as the latter is split off, is often of a light cream or pale yellow colour, and in such cases its removal is easy. Where, however, a dark red cuticle occurs, heavier milling is necessary for its removal, involving loss by the production of a greater proportion of rice bran. Even then there remains a certain proportion of streaky grain, with a tendency to a pinkish tinge, in the finished rice sample.

After removal of the cuticle the kernel may show up as a somewhat translucent pearly grain—the appearance most sought after—or it may present an opaque chalky white appearance. From the food point of view there is little objection to the latter, or even to the presence of red colour ; but, as a product, the pearly kernel is greatly preferred, and we shall see later how this is enhanced by artificial means in order to increase the commercial value of the rice.

These features of coloured cuticle and chalky kernel, may be found within the major classifications already referred to, that is, either in hill or lowland rice, in long- or short-stalked grain, in heavy round or light thinner grain, in rice with awns and rice without ; it is only by rigid selection that improvement can be brought about, and this will be dealt with later.

We will now consider the distribution of the rice plant and its cultivation under various conditions.

CHAPTER III

PRODUCTION AND DISTRIBUTION

ANY estimate of the world's production of rice must necessarily be approximate only, particularly when one takes into account the variations which occur from year to year in the crops of the principal rice-growing countries.

It is extremely difficult to get reliable figures of cultivation and yield, from purely native sources where no machinery exists for obtaining official statistics.

In British Possessions, in the United States of America, in Eastern Territory under foreign control or advice, and within the Japanese empire, reliable figures can be ascertained and are accurately recorded. It is otherwise in an enormous country like China, for example, where all the rice grown is consumed internally and none is exported, so that estimates of production there vary within the widest possible limits.

Various bulletins of the Imperial Institute, particularly the special Indian Trade Inquiry—Reports on Rice—give probably the most reliable average statistics available. Owing to natural crop fluctuations which occur from season to season, the average total figures presented are not likely to vary appreciably.

These bulletins give the total world's production of cleaned rice as approximately 60,000,000 tons per annum; and of this enormous crop some 35,000,000 tons are obtained from British India alone, that is, from the Peninsula of India including the Province of Burma.

The Chinese Empire has a population of one-third more than that of the Indian Empire, and, although climatic conditions in parts of the former are not favourable to the cultivation of rice, one may be allowed to assume that China, in a good season, may produce as much as 30,000,000 tons per annum, although much lower figures have been suggested.

Leaving China on one side for the moment, however, let us look at the figures of output for the rest of the world. As these have been compiled with the greatest care by the Imperial Institute, the immediately following figures are reproduced by the courtesy of that Institute.

Country.	*Production in Tons. per Annum.*
British India, including Native States	35,000,000
The Japanese Empire, including Korea and Formosa	10,600,000
The Netherlands, East Indies, including Java and Sumatra	4,250,000
French Indo-China	3,500,000
Siam	2,500,000
[These are the great rice-producing countries of the world, and there is a considerable drop before we come to the next largest producers.]	
United States of America	520,000
Philippine Islands	500,000
Madagascar	450,000
Egypt	366,000
Italy	320,000
Brazil	250,000
Persia	250,000
Ceylon	172,000
Transcaucasia and Russian Turkestan	170,000
Spain	150,000
Malaya	123,000
[Once again we have to record a considerable drop in the importance of production.]	
British Guiana	41,000
Bokhara and Khiva	40,000
Peru	40,000
Mesopotamia	30,000

Mexico and Ecuador and Hong-Kong also, are credited with 15,000 tons each.

It is understood that the tonnage-output is calculated in terms of *cleaned* rice—that is, rice from which the outer husk, the inner cuticle (as represented by the bran or meal), and the rough broken grain are excluded. For convenience of calculation the proportion of cleaned rice to threshed paddy or rice in the husk, is taken as 6·25 to 100 by weight, and, roughly, 1 to 2 by volume.

The balance of the world's production is made up by British North Borneo, Fiji, Guatemala, Argentina, Dutch Guiana, and several rather negligible sources of supply.

It will be observed that the mass production of this cereal is contained within the south-eastern portion of Asia, running—west to east—from Persia to the Philippine Islands, and—north to south—from the Yangtse valley to the Netherlands East Indies, and represents some 57 million out of a world's total of 60 million tons per annum, excluding China. In the latter country, the principal production of rice is in and to the south of the valley of the Yangtse river.

While the foregoing total figures may be taken on the average as fairly indicating the facts, one has to remember the variations which may occur from season to season in any one country.

To take one example only, let us examine the figure, given for the Philippine Islands, of half a million tons.

The Rice Number of the *Philippine Agricultural Review* for 1921, shows the following remarkable variations—

For the year ending 30th June.	*Tons of Paddy.*
1909	750,000
1912	400,000
1913	1,000,000
1915	766,000
1917	1,215,000
1918	1,540,000
1919	1,450,000
1920	1,485,000

If these figures are corrected to give the corresponding yield of cleaned rice, it will be seen that this varied from about 250,000 tons in 1912 to about 960,000 tons in 1918. On the other hand, and as has often happened, the crop in, say, Japan or Siam might quite easily be 30 per cent below normal in any given year, while the crop in Indo-China or Java might be a record one. No doubt the figures average out sufficiently closely for our present purpose, which is indicative only.

Owing to the demand for this staple native food, efforts are being made to encourage its cultivation in areas not hitherto connected with its serious production. Right across Equatorial Africa the cultivation of rice is being increased, and quite useful crops are also now being produced in Manchuria, particularly since the Japanese occupation. While heat and moisture are alike essential to the cultivation of rice in bulk, it does well in countries where intense cold prevails for a portion of the year, as, for example, in the Russian Caucasus, the Himalayas, Japan, and Manchuria.

Although production in Europe is relatively unimportant, the quality of the rice grown in the Novara Province of Italy, as well as in Lombardy, and in the neighbourhood of Tortosa and Valencia in Spain, is of a high order. Spanish rice is much prized in the principal European markets ; the finest qualities are grown from Japanese seed and command a high price. This rice is also commonly imported into France in a partially milled condition—being subject to a much lower duty than if imported in a highly finished state—and it is then re-milled and finished in ports such as Marseilles.

The cultivation of rice has also been undertaken in Bulgaria and Greece and is capable of extension there ; but unfortunately, the War and its aftermath have not permitted that development which might have taken place under happier auspices.

Extending our survey still farther west, the Southern States of the U.S.A. provide us with some of the finest rice to be found in the world's markets. We are all familiar with the name "Carolina Rice," but the output of Carolina and of Georgia, formerly the principal rice-producing States, has been far exceeded by that of Louisiana, while Texas and Arkansas have also put the older rice States in the shade.

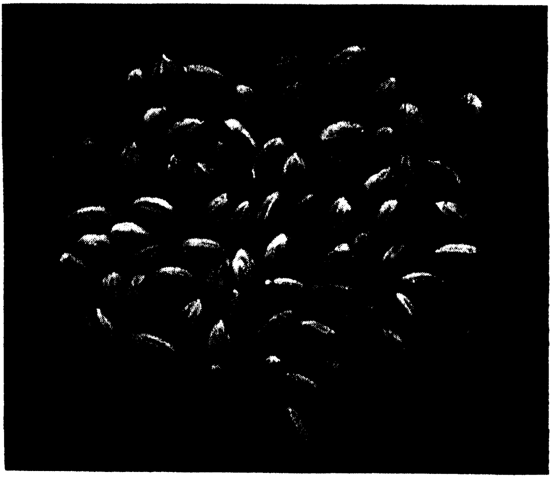


FIG. 3

SPANISH-JAPAN PADDY GRAINS

Reverting to the East, it is of interest to note how some of the great producing countries like Burma, Siam, and French Indo-China, export a considerable proportion of their crop; others—notably China—export none. Japan and Java, which both produce a high-grade grain, export for European consumption and import large cargoes of cheaper qualities for local native use.

We have seen that the production of British India, as a whole, amounts to some 35,000,000 tons per annum.

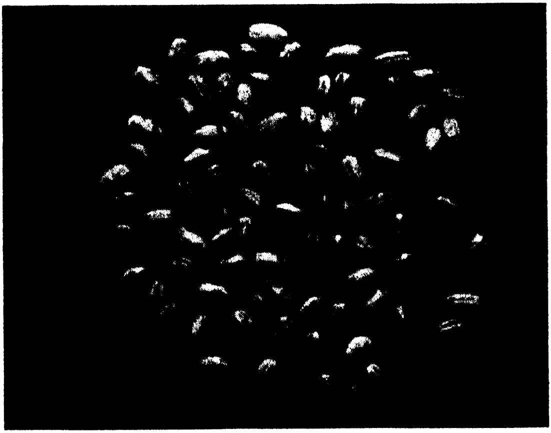


FIG. 3*a*

SPANISH-JAPAN HUSKED RICE

The three contiguous States, Bengal, Behar, and Orissa, in the north-west corner of the Bay of Bengal, produce together nearly 17,000,000 tons; Madras Province, 5,500,000 tons; and Burma, about 4,500,000 tons. The yield of the United Provinces is at least equal to that of Siam, while the Central Provinces, Assam, and Bombay are responsible for 4,000,000 tons, or nearly as much as the total crop of the Netherlands East Indies; even Sind grows nearly as much as the United States of America. With the exception of Burma, which exports about half its crop, and Behar, which exports a relatively small amount of high-class "Patna" rice, practically the whole of that huge quantity is cleaned by simple methods and is consumed within the Peninsula. Burma is the principal exporting country in the world, shipping some 2,500,000 out of 4,500,000 tons of cleaned rice per annum. Indo-China exports about one-third of its production. Siam normally exports about half of its crop, but as that crop consists of two distinct qualities, "garden" rice and "field" rice, the former or finer finds its way principally to Europe, while the lower quality is absorbed locally.

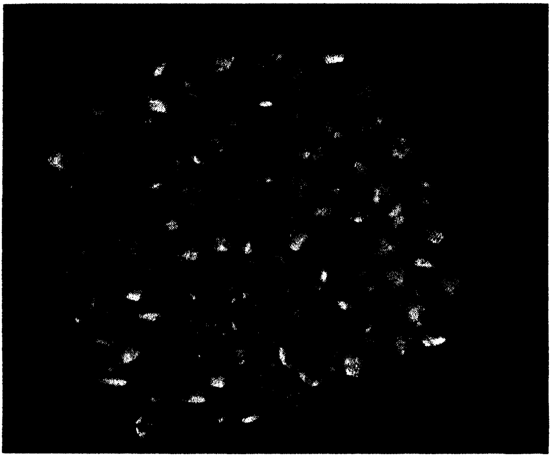


FIG. 3*b*

SPANISH-JAPAN POLISHED AND GLAZED RICE

The internal trade of India shows an interesting interchange of rices, as there are marked differences between the quality of certain varieties in certain districts and those cultivated in other districts, a difference of 2 or 3 rupees per maund (roughly, 4s. or 5s. per cwt.), being not uncommon as between the higher and the lower grades. The rich Indian, in whatever part of the country he may reside, can afford to gratify his tastes ; and, while his expenditure in other directions indicates that some of these tastes are extremely simple, he is quite prepared to gratify his desire for the finest rice procurable.

The humble coolie, however, though living in a district where such fine rices are cultivated is unable to buy them, and therefore, poorer qualities are brought in from other districts for his food.

Just as crop outputs vary from season to season, so also do prices, though by no means always in the same ratio. Shortage of crop in any one large producing country may mean a rapid absorption of the excess crop of a neighbouring country, with the result that rices from the latter, though readily saleable in European markets, may not appear for a season in these markets except in relatively small quantities and at considerably enhanced prices.

It will be seen, therefore, that there is usually a good market for both better and poorer qualities. Broadly speaking, unless in quite exceptional circumstances, the world's production balances itself according to requirements.

As certain rice-growing areas become more and more congested or, in other words, as the area available for cultivation becomes either more completely planted, or restricted by its utilization for other purposes, fresh efforts are put forth in other countries to develop rice cultivation where soil and climate are favourable. Where the limit of area is reached, the only solution is more intensive cultivation.

CHAPTER IV

CULTIVATION

THE cultivation of rice may be divided broadly into two categories—upland or so-called *dry* cultivation, and lowland or *wet* cultivation.

In both cases a fairly high air temperature and an adequate supply of moisture are essential. Hill rice has been cultivated at an elevation over sea-level of as much as 7,000 ft. in the Himalayas; at 4,700 ft. in Nepal; at 4,300 ft. in Java; while in central Madagascar it is regularly grown at anything from 2,000 to 3,000 ft. up. The rice seed is sown broadcast as in the case of wheat, but it is allowed to mature where sown and is not transplanted. Excellent varieties are grown, but the yield per acre is not so great as is obtained from lowland or wet cultivation, in which the young seedlings are transplanted at an early stage. In cultivating true hill rice great attention must be paid to the period of rainfall, as on this alone the crop depends for the supply of the large quantity of moisture required for its growth.

There is what might be termed a half-way house between the true hill and the ordinary lowland cultivation, and that is the hillside method of cultivation so widely practised in certain mountainous countries, such as Japan, Java, Ceylon, and Madagascar. Owing to the prevalence of a moist climate and liberal rainfall, irrigation is effected by the regulation of mountain streams. As the traveller journeys by road or rail, rising higher and higher, he sees the wonderful terraces—often laid out in the narrowest of strips, in which the young shoots are transplanted. Water is maintained at a suitable level by low earth parapets—*bunds*, as they are called in the Far East, or *levees* in the West—which, while ensuring the retention of a sufficient supply of moisture, are also arranged so that every section may be drained as required and water prevented from stagnating on any part of the fields. Needless to say, the sections have to be accurately level in order to maintain an equal depth of water over the plants. In such cases the water flows practically continuously over the cultivated area, from the higher to the lower levels; it can be by-passed when necessary, the terraces being drained by small cuttings in the low parapet walls, discharging into suitable channels, to carry off the surplus.

Note this distinction between the true hill rice and that grown under what we have described above as hillside conditions: the former is not planted out after the seedlings have sprouted, whereas the hillside rice is transplanted in the same way as lowland rice.

As the overwhelming proportion of the world's production is cultivated under lowland conditions, we shall proceed to deal more fully with this method.

Apart from purely botanical varieties, there are certain rices which are better suited to earlier, and others to later, planting. Not all rice-growing countries enjoy the same rainy season; and in some a specific time or duration of rainfall may have to be disregarded if other conditions are unsuitable. In such cases the necessary supply of moisture is provided either by rivers contributing automatically to a well-planned irrigation scheme, by great tanks filled during the actual periods of rain, or by pumping plants of large capacity, discharging enormous volumes of water into canals and thence into subsidiary channels.

A dry and torrid zone may be extremely unfavourable to the plant even if ample artificial irrigation is available, as excessive heat—dry heat—may do serious damage to the young crop, even though there be a reasonable supply of water over the roots. This, no doubt, is one of the reasons accounting for the great variation already commented upon in connection with the Philippine crop, as rainfall in these islands is often erratic while sun temperatures are high. Exactly the same cause has operated to hinder the development of rice culture in Australia, certain parts of which are otherwise eminently suitable, as the production of excellent experimental crops goes to show.

Let us now look for a little while at the methods of cultivation adopted in some of the principal rice-producing countries.

Preparation of the Land. As we must assume some starting point, let us take as the first step the preparation of the fields ; let us suppose that a crop has been harvested and that the moment of re-commencing the whole sequence of operations has arrived. Whatever be the customary method of harvesting, there is usually a considerable amount of cleaning up to be done, and the stalks, whether left long or short, will require to be dealt with first.

The ground having been cleared, the tufts of straw or stubble are frequently burned where they stand, and immediately thereafter the land is ploughed, let us say, in December. After a brief period it is again ploughed once or twice—in some cases in both directions, that is to say, from east to west and then from north to south—after which it is left exposed to the sun and the weather till March-April, when the whole area is again gone over and the large clods are broken up. Soon the first light rains will come to refresh the soil, and once they have commenced, the fields are again subjected to one or more ploughings and then harrowed. By this time the rains

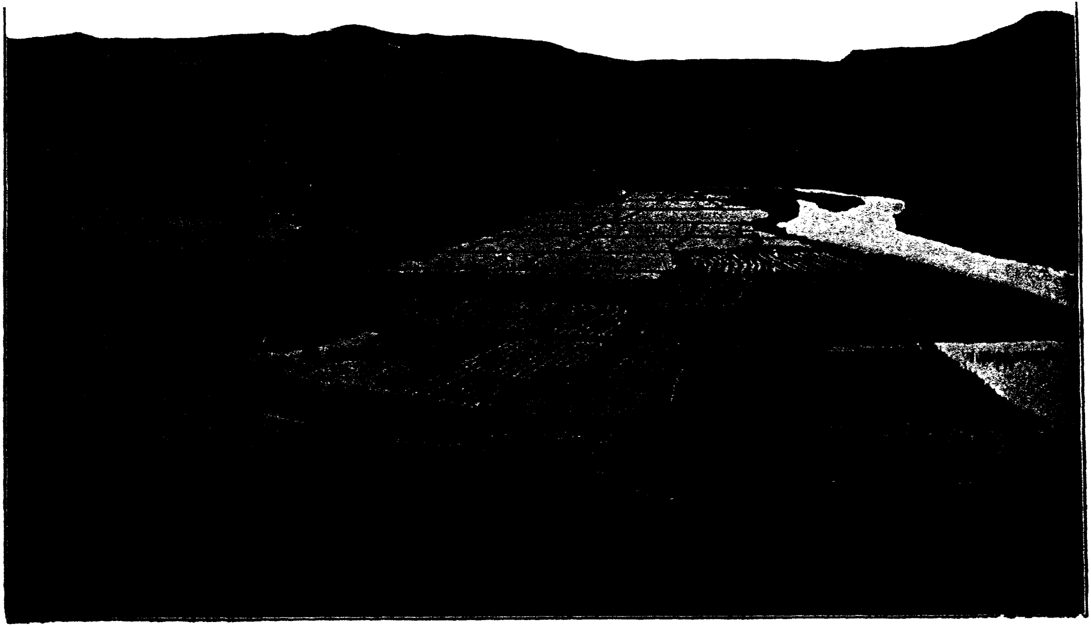


FIG ·TYPICAL RICE FIELDS

are probably setting in in earnest and the fields are ready for sowing.

Sir George Birdwood, in his interesting book, *Sva*, gives the following graphic account of the preparation of rice fields which came under his observation—

" Hindus habitually use manure in the cultivation of rice : sometime in the hot season the land is strewn with all the rubbish and refuse of the household and homestead—floor sweepings, old thatch, old clothes, being burned together in the fields. When the rains set in, this mess is trodden in by men, women, and children, assisted by cows and buffaloes, until the whole is kneaded into a plastic cohesive mud called " chikal," in which the seed rice is sown. The effect of this is to bake the ground immediately below the upper layer of fertile mud into an impervious bottom, which prevents the rain draining through and escaping."

It is not, however, universal practice to manure the land in preparation for sowing—at least, not to manure it in the ordinary sense of the word. For instance, the addition of manure is unnecessary in deltaic or alluvial country where the ground is automatically and annually enriched by deposits from overflowing rivers.

In Egypt, where alluvial deposits occur on rice lands owing to the overflowing of the Nile, it is stated, in the *Text-book of Egyptian Agriculture,* published by the Ministry of Education in that country, that " rice is never manured, and it is not likely that manuring would have much effect, as the large quantity of water necessary would remove any application before it could be utilized by the plant." To compensate for the exhaustion of the soil, it is customary to sow a crop like berseem (clover) ; the value of clover as a restorative crop has been recognized for many centuries in other Eastern lands besides Egypt. On the borders of the Nile it is

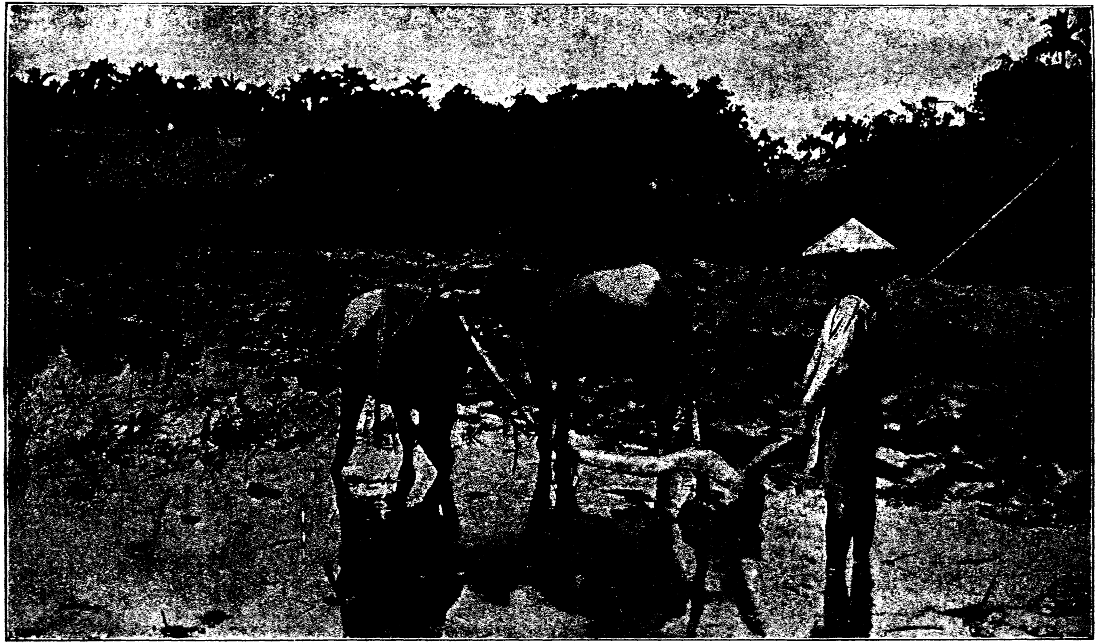


FIG. 5.—BUFFALO PLOUGHING IN ANNAM

not uncommon practice to sow cotton one year, then rice, and to follow up rice with clover, which, in common with other leguminous crops, has the power of absorbing free nitrogen from the air and converting it into plant food.

As two or three cuttings may be obtained from one sowing of clover seed, this becomes a valuable food for animals ; where the condition of the soil permits, these animals are allowed to graze on the clover land, thus leaving the roots in the soil so that their full manurial value is obtained when ploughed in at a later day.

Rice does not impoverish the soil to the same extent as wheat and certain other cereals, and in many cases irrigation water, even if it be not overflowing river water containing silt deposits, does in fact contain a certain amount of fertilizing agents. Experience shows, however, that adequate manuring of the soil produces as beneficial results in the case of rice as in that of other crops.

To cite another out of many typical cases, let us look at the method of field preparation practised in Madras. Here one may see rice lands irrigated by means of so-called " tanks " which become filled during the rains, and from which the water flows through suitable channels. When a state of sufficient saturation is reached, the land is ploughed four or five times, both lengthwise and across, until the whole area is reduced to the condition of one vast puddle. The soil is then fertilized by the addition and thorough admixture of leaves and suitable plant roots, farm dung, and ashes resulting from the combustion of any convenient material, the mixing process being effected most satisfactorily by repeated further ploughing. The land is allowed to dry off for a little, the clods being broken up and levelled by the common process of drawing a beam of wood over them ; the surface is again reduced to mire by the

Fig. 6

IRRIGATION IN INDIA

addition of further water, and the field is then ready for sowing.

No account, however condensed, of the cultivation of rice fields would be complete without a brief reference to the agricultural methods practised from time immemorial by the Japanese.

In the Land of the Rising Sun, if anywhere, rice cultivation has become both an art and a science.

It is well understood that rice thrives best with an almost unlimited amount of humus: while chemical manures may have a definite value, what rice wants is a large quantity of additional soil-forming material. To this end, the Japanese employ every conceivable substance to enrich their rice fields, from leaves, and even the lighter branches of trees, grasses, clover, and other leguminous refuse, to burnt-out native bricks, suitably ground down, ashes, and other refuse. That, however, does not complete the tale: like his near neighbour, the Chinaman, the Japanese farmer makes full use of the large amount of night soil which is available from a population greater per acre of cultivated land than in many other countries. This valuable material is not sent out to sea and wasted, but is conserved in large brick receptacles, where it is added to other accumulations of material collected for manurial purposes, including the mud recovered by dredging from the vast network of irrigation canals which intersect the agricultural districts of the main islands.

One hesitates to compute the amount of manure thus compounded and added to the fields, but it is enormous; not only so, but experience has shown it to be well balanced, and to provide precisely those constituents which are required by the intensive methods of cropping of which our friends are so justly proud. In Japan there is no waste, either of land, material, or time; and so far as Japanese rice is concerned, whether as food or seed, it has been distributed all over the world to the marked benefit of mankind.

While dealing with the question of land preparation, it is fitting to refer for a moment to the matter of the soil itself, although this opens up rather a large field for investigation.

FIG. 7

HOEING RICE IN JAPAN

Certain rices, particularly upland or hill varieties which it is not intended to transplant, thrive best in a relatively free, light loamy soil ; lowland varieties, or those grown on terraced hillsides, and in any case those which are sown with a view to being transplanted, do better in a heavier soil, preferably with the addition of as much humus as may be available. A desirable common characteristic is the presence of a clay subsoil to prevent the loss, by percolation, of the water essential for cultivation. Light, sandy soils are unsuitable as they will not retain sufficient moisture ; and where irrigation water has to be provided by artificial means, considerable additional expense would be involved. Heavier soils are in any case more likely to contain a greater supply of plant food.

Good drainage is important to permit of getting the water away quickly when it is desirable to do so, as for instance, at the ripening period ; this is important not only in order that the crop may be properly matured, but also because the dried soil facilitates harvesting operation, particularly where it is possible to harvest by machinery. Further, if it be possible to drain the land thoroughly and keep it drained sufficiently to permit of growing other crops which do not require the large amount of water needed by rice, the yield of the latter is improved when its turn comes again. A soil too rich in nitrogen is harmful, as it induces growth of mere vegetation at the expense of grain. Soils rich in alkali are not disadvantageous, as the large quantity of water required keeps the alkali sufficiently diluted. Lateritic soils are favourable ; a considerable proportion of the Indo-China crop is grown on such ground.

As rice is not a deep-rooting plant, and as shallow sowing is almost universal, deep ploughing is unnecessary unless at intervals of a few years, and where there is no rotation of crops.

CHAPTER V

SEED SELECTION, SOWING, AND TRANSPLANTING

SEED selection, it need hardly be said, is a matter of the highest importance which is fortunately receiving more and more widely the attention which it merits.

Evidence of the extraordinary interest attaching to seed selection and the care taken in this process is available in the relative bulletins and reports of the Departments of Agriculture of the principal rice-growing countries. The author also recommends perusal of the reports of the " Congrés International de Riziculture," which contain the results of many experiments carried out in different parts of the world. Every country in which rice production predominates is provided with experimental culture stations. Tests of innumerable different seeds are continually being carried out, not only with the many varieties indigenous to the country itself, but also with imported kinds. These tests are undertaken to ascertain the best maturing varieties under different conditions as to heat, moisture, and season, and to determine the resistance of this or that seed to unfavourable outside influences.

Care must be exercised in arriving at conclusions in such matters, as although it may be possible to cultivate an imported variety which will mature more rapidly, or give a greater yield per unit of area sown, or resist more effectively adverse outside influences, it is also possible to find that the new rice has not, for one reason or another, the same commercial value as the indigenous variety which it is proposed to replace.

In Oriental countries, where rice plays such an important part in the food of the people, there is great conservatism and prejudice in respect of certain varieties ; but in addition to this, the author has come across cases where the consumption of a consignment of rice of a quality similar to that usually eaten, but grown and milled in another area where it was beneficially consumed, has produced obvious though not necessarily serious intestinal derangement.

The selection of appropriate seed becomes much more important in those countries where the area under cultivation is rapidly reaching its possible limit. In such cases it is obvious that the selection of such varieties as will give the best results from every point of view, should be the aim of those controlling the agricultural fortunes of the district in question.

In other countries, particularly those cultivating rice destined for high-grade European or American consumption, certain characteristics are specially sought after and encouraged. Bearded rice is usually a nuisance ; rice with a red cuticle is regarded as most objectionable. A fine cuticle and a thin husk are always preferred. A pearly translucent kernel is of great advantage in the production of glazed or faced rice for Occidental markets, and so on. It is in relation to these features as well as to heavy yields, resistance, and true food value, that seed selection plays such an important part.

A method of final seed selection frequently adopted after selection based on grain characteristics is completed, is by the immersion of the chosen grain in a solution of salt (in Japan and in Siam), or in a solution of sugar (in Java). The more solid grains sink, while the lighter and less valuable grains are floated off ; by this means it is possible to detect and reject a considerable percentage of defective or pest-infected seed.

After such processes are concluded, the chosen seed should preferably be sifted and winnowed to remove finally any risk of the intrusion of weed seed which, if included with the rice, will inevitably cause trouble. There is quite sufficient possibility of this arising in any case during the growth of the plant ; but much can be done to reduce this by careful examination of the seed before sowing. It is a well-established fact that the communal or travelling threshing machine, is often a source of trouble in this connection, not only with rice but with other cereals. Reference bearing on this was recently made by Professor Biffen, F.R.S., when dealing with the question of " throw backs," or reversions, in connection with wheat.

It is impossible to avoid the collection of weed while grain is being harvested, and weed seed is consequently threshed and stored with the true grain. Such machines, travelling from one part of the country to another, are sure to carry weed unless the utmost care is taken to see that they are thoroughly cleaned out between operations in one centre and in another.

These preliminaries having received due attention, the selected seed is dealt with differently according to the custom of the country.

Broadly speaking, where rainfall or irrigation water is plentiful, the seed is sown broadcast in its ordinary dry condition ; but in many cases it is allowed to germinate before it is sown. In the latter case it is put in an earthenware pot, immersed in water, and covered up by a cloth, for several days until germination takes place. After this, it is taken out and spread in the shade, away from the direct rays of the sun, and allowed to dry off, when it is ready for sowing ; obviously, care is required for this operation to prevent damage to the sprouted seed.

After sowing, the field is sometimes lightly raked over to ensure retention of the seed in the muddy surface.

When mechanical seeding is adopted, as in some instances in the United States of America and in Italy, the selected seed is frequently placed in a vessel containing a mixture of 66 per cent of clay and 33 per cent of chalk, stirred up in water. This has the effect of slightly encrusting the seed and rendering it heavier, so that it is not so liable, as it would otherwise be, to displacement by wind or other causes if broadcasted on ground covered by a layer of water.

Rice is not a deep-seeding nor a deep-rooting plant, and is rarely sown, except when a drill-seeder is used, to a depth of more than half an inch. In many cases it is simply allowed to remain on the surface of the ground; where more scientific methods are possible, it is better sown dry, in drills, rolled or lightly harrowed thereafter, and then adequately moistened to ensure germination.

The proportion of seed to be sown per unit of area varies enormously, depending chiefly upon—

1. The variety of rice planted.
2. The conditions of planting, i.e. whether lowland or hill ground.
3. Nature of soil.
4. Climatic conditions.

In Burma, the rate of seeding in many districts runs about one basket (say, roughly, 46 lb.) of seed per acre of *transplanted* field.

Carleton (U.S.A.) puts the range of seeding at from one to three bushels per acre, with 90 lb. per acre for California, but this with a short-kernelled variety; thicker sowing is necessary for long-kernelled grain. Obviously, more seed is required in broadcast sowing than where advanced methods, soil, and other local conditions, permit of drill-seeding. Again, in Nepal, where a fine

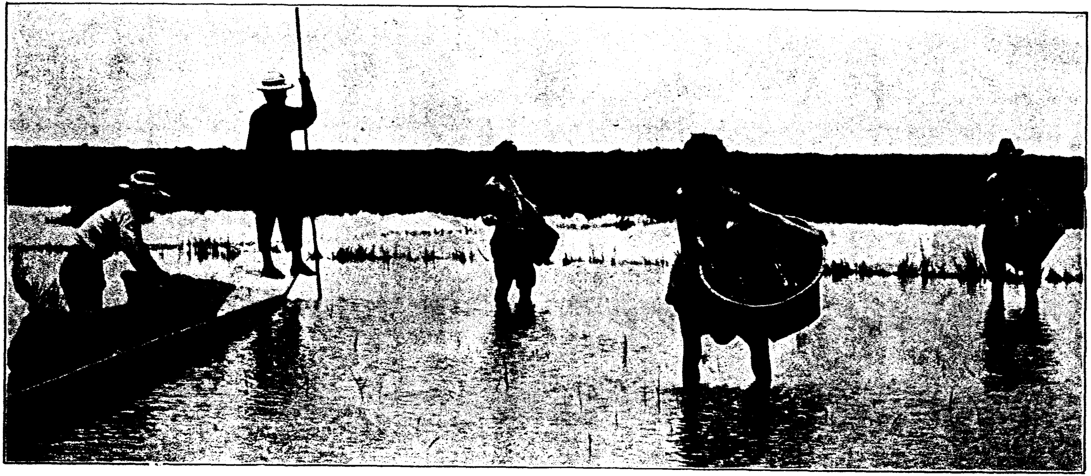


FIG. 8

SOWING SPROUTED SEED IN SIAM

variety of rice is grown, and is planted dry in the middle of May, the native farmer drills a series of holes with his finger, and inserts four or five seeds in each, the " drills " being about a span apart.

The last report of the International Rice Congress at Vercelli, Italy, gives rates of seeding as 100 to 150 kilos. per hectare—about 90 to 130 lb. per acre ; probably an average varying between 50 to 80 lb. per acre is near the mark, but a ratio which will suit certain seeds in a given area under certain climatic conditions, may require to be varied within wide limits for other conditions. Here is an account of the seeding process in Persia as recorded by Rabino and Lafont in their pamphlet, entitled " La Culture du Riz en Guilan," that part of Persia around the delta of the Sefid Roud, a river which flows into the Caspian Sea.

Every spring this river overflows its banks and deposits a layer of silt over what is otherwise dry, sandy country. As soon as the water has subsided sufficiently, the villagers get out their flat shallow-draft canoes and stock them with seed previously steeped for three days in cold water to induce germination. This seed is scattered broadcast over the surface of the land from which the water is now receding, and which has thereby been covered with a layer of fine alluvial soil. No further attention is given nor is any attempt made in the direction of manuring, or of further irrigation, the outcome being left to nature until the grain is ready for harvesting.

This is an ideally simple method of cultivation which is profitably carried out with a minimum expenditure of labour, not only in Persia but in other parts of the world where nature is kind and human wants are few. In parts of East Africa where there is but a brief rainy season lasting from six to eight weeks, rice is sown as soon as the first rains break ; and although there is no

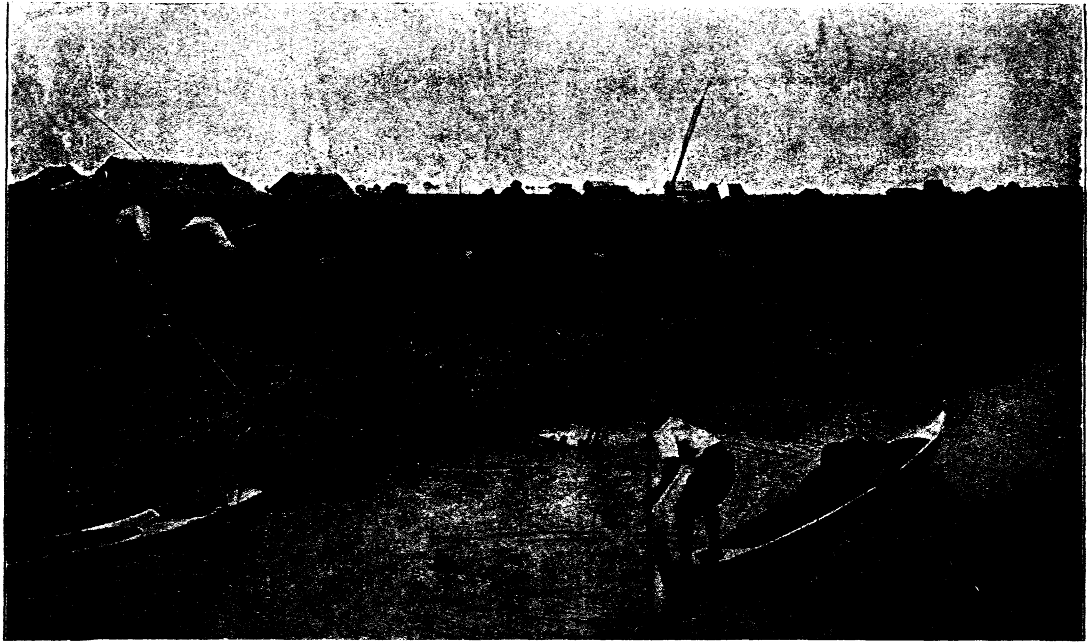


FIG. 9.—IRRIGATION IN SIAM

attempt at irrigation, no manuring, and no transplanting, a good crop of excellent rice is obtained.

This is roughly the method adopted in planting hill rice also ; but whether in such cases or in the case of rice to be wet-grown, it is desirable to assure a relatively dry soil condition for a few days after seeding until the young shoots appear and the plants are established, when water, in the case of wet rice, should again be admitted to the fields.

It may be asked, " What is the proper time for sowing rice ? " The reply to that question differs greatly according to circumstances.

If we turn to Bengal, for instance, we find that there are three principal crops known respectively as " Aus," or early autumn rice, which is sown in April-May ; " Aman," or winter rice, sown in May ; and " Boro," or autumn rice, sown in June-July. These three crops are harvested in July-September, November, and September-October respectively. From this it will be seen that there is a considerable difference in the maturing period, and that for eight months in the year the land, in some part or another, is under rice.

In Siam, there is a distinct winter rice and an equally distinct summer variety, the one, " Khao nak," being sown in midsummer (June-July) and harvested in December-January ; while the other, " Khao bao," is sown in January-February and harvested in May-June.

In Burma, we have also three principal varieties of which one, " Kaukyin," is remarkable for its early maturing qualities, as it develops fully in from seventy-five to ninety days, being sown in August and reaped in November. Another main variety is known as " Kaukgyi," or " great paddy," which is a long-lived rice requiring from 120 to 150 days to attain maturity ; this is usually sown in August and harvested in January.

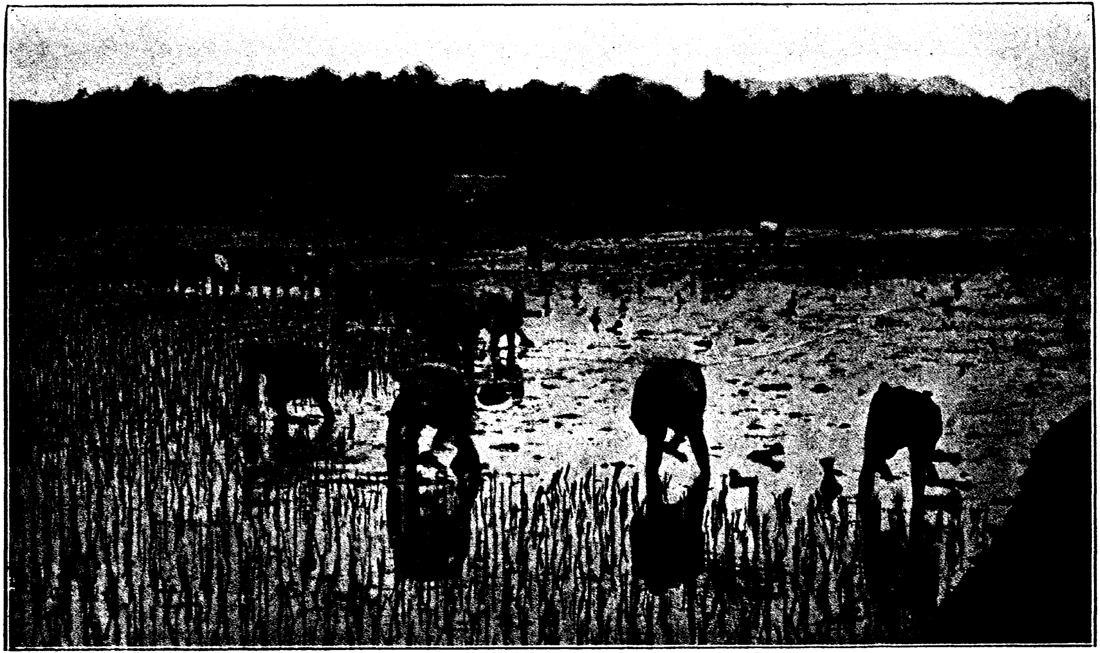


FIG. 10.—PLANTING OUT YOUNG RICE

Finally, there is the intermediate variety, " Kauklat," which is sown in July-August and harvested in December. It will be seen that the period of cultivation in Burma is fairly constant, being spread over a matter of six or seven months, from July to January, the planting synchronizing with the complete breaking of the Monsoon. It means, further, a big supply of paddy or unhusked rice coming down from up-country to the big milling centres like Rangoon and Bassein, round about December-January.

We have been writing here of countries possessing a relatively uniform temperature, or at least having no really cold weather. As one goes farther north into Tonkin, China, and Japan, there is a marked difference between summer and winter, and the winter is usually appreciably longer and colder than that experienced in the British Isles.

The same remarks apply to districts like Nepal, the Himalayas, and to Manchuria, in all of which extremely cold winter weather is experienced. As one travels west, Spain and Italy show wide temperature variations, and the times of sowing and harvesting must be determined largely by temperature conditions.

In Japan, there is no great difference from season to season in the period of sowing : spring is often cold and raw, but is followed by a hot summer which, thanks to the agricultural instincts of the Japanese and their excellent system of irrigation, is fully utilized to produce their abundant crops which mature, according to variety and district, in from four to six and a half months.

In the United States, sowing usually takes place during April, with some varieties earlier and others later ; the maturing period does not differ greatly from that in, say, Japan.

Transplanting. We have seen that it is customary to transplant " lowland " rice, the production of which is considerably increased thereby ; the same applies in the case of hillside rice to which reference has been made.

Five or six weeks after the seed is sown, the young shoots are sufficiently developed to permit of being lifted from their original bed and of being transplanted into fields which have been prepared for their reception. This is a somewhat tedious operation, yet it is wonderful to watch the rapidity with which it is done. Sometimes it is effected by two separate groups of men and women, one group moving backward in a row as they drill hole after hole in the mud with a short stick, while the other group, armed with bunches of seedlings, move forward, inserting these in the holes made by the first group. The plants are usually placed 8 in. or 9 in. apart.

When transplanting is over, water is turned on to the fields, which are usually kept submerged until the grain is verging on maturity, except where it has to be run off to permit of weeding or to counteract the attacks of water-weevil. Apart from the fact that ample water is necessary to plant development, it tends to check weed growth ; it is important that the supply of water be kept flowing, however gently, so that it is always being renewed ; stagnant water must be avoided, as it encourages weed and insects.

The effect of these young rice fields is particularly beautiful ; after months of dry, barren land, or muddy manured fields, there are few more refreshing sights than the exquisite green of the young paddy plants, especially when viewed against the rich red of a laterite soil.

CHAPTER VI

WEEDING, HARVESTING, AND THRESHING

During the growing period careful attention must be given to weeding ; this is most important in countries where the rice is not more or less constantly submerged, but where artificial irrigation is required. It is also most important in countries where rotation of crops is practised, as well as where other crops—such as maize, millet, or sugar are grown in relatively close proximity to the rice fields.

Weeds grow faster and are hardier in hill fields than in lowland planting, and they are also more difficult to eradicate where rice is sown broadcast, rendering access between the plants almost impossible. The cost of weeding may become prohibitive, rendering the harvesting of the crop entirely unprofitable. Apart from that, the presence of weed in considerable amount reduces the quality as well as the quantity of the yield.

In Italy, the cost of weeding only may, in certain cases, be as high as 25 per cent of the gross revenue derived from the crop ; and in the Philippine Islands as much as 50 per cent of the crop may be ruined by weed.

In the majority of large transplanted rice areas, weeding must be done by hand, sometimes even with the hand, or else by hoe. A simple form of mechanical weeder somewhat resembling a small lawn-mower, is used in Japan ; it is only in highly developed European or American rice fields that large mechanical weeders may be employed, and these require the water to be drained off before they can be used.

If labour is sufficiently cheap (although even in the

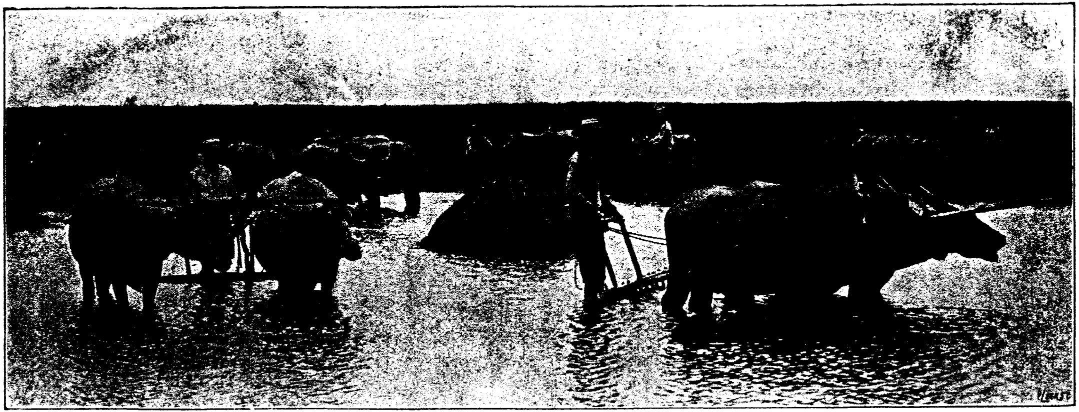


FIG. 11

HARROWING IN JAVA

most backward Oriental countries so-called cheap labour is rapidly disappearing), it is probable that hand-weeding is most efficacious in preventing dissemination of weed; whereas in the case of mechanical weeding, especially if the weed has been allowed to attain a certain degree of growth, it is apt to be thrown down and forced into the soil.

Harvesting. While an ample supply of water is necessary during growth, it requires careful regulation as the plant flowers, and should be withdrawn altogether some days before harvesting; as soon as the grain begins to turn in colour, it should be allowed to mature in a dry state. The actual moment for harvesting is usually decided upon by the colour of the stalk, although a simple test which is often applied is to try the hardness of the grain with the teeth.

In nearly all the countries which are responsible for the largest share of the world's rice production, harvesting is done by hand, and by native labour, it being in many cases impossible to employ mechanical reapers even if the native farmer could afford to purchase such modern machinery. Moreover, the straw is valuable to him, not only as bedding, but also as fodder for his cattle. Whether the grain is harvested by cutting the straw near the ground or simply by cutting off the heads, depends on whether the cultivator does not or does require the straw for certain specific purposes. When harvesting the heads only, this is done simply by plucking them off in twos and threes at a time with the fingers; but if the grain is reaped with the straw, it is necessary to use some form of sickle. With long-bearded varieties, especially if wet, there is a tendency for the heads to become matted, which greatly increases the labour involved.

In a number of the big rice-growing areas—as, for example, in Burma—local labour is quite inadequate to harvest the grain, so that from November to January particularly there is a big influx of population from other parts of India.

In many districts the harvesters are paid, not in cash but in kind, and a definite percentage of the crop is allotted to them in return for their services.

Whether plucked by the head or reaped in the stalk, the rice is tied into bundles of convenient size, and removed from the field to neighbouring drying grounds specially prepared beforehand, to permit of the rice—and this applies particularly to " wet " varieties—being adequately dried before being threshed and stored as grain.

The preparation of these drying grounds involves a considerable amount of work; the basis is usually local mud trodden out hard, and mixed with some binding material, such as cow-dung, which is at once convenient and economical.

As harvesting takes place during the dry season, the risk of rain interfering with the drying process or with the ground on which it is effected, is remote.

In the case of crops grown at considerable altitudes, care has to be exercised in order that the grain spread out on these grounds may not suffer from cold air at night time. There is, in addition, the risk of " sweating" caused by contact between the cold night air and the surface of the ground, which has been well warmed during the day.

A simple method of drying rice is to tie it in bundles, which are carried from rails attached to bamboo posts, so that the grain is not in contact with the ground but is entirely free, and may be ventilated by any breezes which may occur during this period; this is common practice in Japan, where the greatest stress is laid, as it ought to be everywhere else, on the adequate drying of harvested grain.

Mechanical harvesting has not made much progress in the great Oriental rice-producing countries, although here and there modern agricultural machinery has been satisfactorily employed when conditions have been favourable.

For one thing, the ground on which most of the great crops are raised is low-lying and therefore liable to be in a more or less saturated state, if not actually on the surface then not far below it ; this renders the utilization of heavy harvesting machinery a matter of difficulty. Again, the fields are usually subdivided into small areas by low, narrow, earthen embankments, or bunds, for the purpose of retaining the water necessary for cultivation ; the passage of mechanical reapers over land subdivided in this way is impracticable, especially in the case of hillside or terrace cultivation. True upland or hill cultivation presents equal difficulties due to the contour of the country.

It is quite otherwise in more modern highly developed rice countries, such as Spain, Italy, and the United States of America, where the culture of this cereal has been brought to a high state of perfection and where conditions are quite different from those in the East.

Labour is much more expensive ; machinery in its most highly developed forms is used in practically every department of industrial or agricultural activity. Repairs can be rapidly effected and skilled operators are easily obtained ; and, what is equally important, the fields are laid out in such a way as to permit of mechanical appliances being employed.

Under these circumstances, not only is the use of agricultural machinery, from ploughing to harvesting,

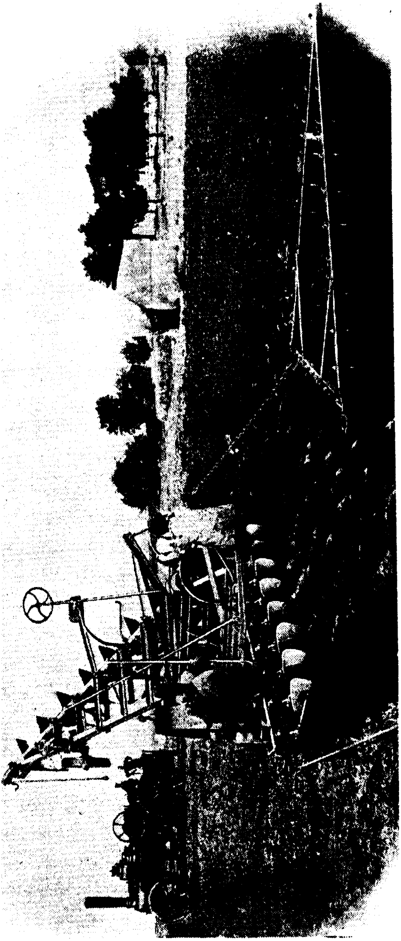


FIG. 12

PLOUGHING TACKLE FOR RICE CULTIVATION

possible, but it is imperative if the production of high-grade rice is to be made a paying proposition.

Once the harvested grain is sufficiently dried, it is either threshed, or stored in the straw in suitable barns.

Apart from the mechanical threshers to which we shall return in a moment, various contrivances are used to remove the grain from the straw. One has seen many different methods employed by native cultivators. In his report on " Burma Rice," Mr. Frederick Noël-Paton, late Director-General of Commercial Intelligence, India, briefly describes the process frequently adopted in that country. A threshing floor is prepared, after the manner of the drying grounds described above. " So far as the supply of cattle admits, threshing . . . is done in the open by teams of about six cattle of all ages, which circle upon the straw and tread out the grain. Some 400 to 500 sheaves are opened upon the floor at one time, and these usually give about 100 baskets (5,000 lb.) of paddy. The rice straw that has been freed of grain is raked aside as the operation proceeds, and the grain and chaff are swept into a heap apart. One lot of sheaves is threshed completely before any others are placed on the floor. The threshed grain or paddy is afterwards separated from the husk by natural winnowing."

This description is applicable to many countries, but the small cultivator may be unable to afford either to buy or to hire the requisite animals. Under such circumstances, one sees, when travelling through rice lands after harvest time, women and children engaged in threshing by raising bundles of rice, in the straw, above the level of their shoulders, and beating the bundles on a board placed edge-wise between two posts. Again, there is the flail, which is still in regular use in some districts where the work is usually done by groups of women working on a threshing floor, the supplies of harvested grain being brought in, and the threshed grain and straw being removed, by other women or children.

Awned or bearded grain is always troublesome at this point, though one would imagine that the manipulation —sometimes pretty severe—of the grain to remove the straw would equally suffice to break off the beard. This, however, is not the case ; a certain percentage of the beards may be removed by threshing, but in the majority of cases the beard is so tough that the grains of paddy have to be flailed, beaten, or otherwise treated over again in order to remove it.

Mechanical threshers are being increasingly employed because their use is not conditioned by the state of the paddy fields or of the weather. Such threshers are usually installed in covered sheds and operated by oil or steam engines ; but, unless the cultivator is sending his paddy direct to the market, it is customary to retain the grain and to thresh it by hand when required. Obviously, this remark applies chiefly to Asiatic cultivation and not to European or American conditions.

There is one other point to which attention can be appropriately enough directed in this chapter, and that is the yield of rice per unit of land planted.

Results vary enormously according to country, climate, cultivation, and seed, and range from 2 cwt. of cleaned rice an acre in Turkey and from 4 cwt. in Greece, to nearly 30 cwt. an acre in Spain. Here again, however, it is difficult to get accurate figures.

In India, where nearly 80,000,000 acres are under rice, the average yield in a good year is about 8½ cwt. an acre ; Indo-China yields approximately 8 cwt.; Siam, 9 to 10 cwt.; and the Netherlands East Indies, about the same.

The countries showing high yields are, as might be expected, those in which special attention is paid to scientific cultivation.

Italy yields 18 cwt.; Egypt and Japan alike, between 21 and 22 cwt.; and Spain, as stated above, reaches the high figure of 29 to 30 cwt. of cleaned rice to the acre.

Among numerous figures in the author's possession relating to the U.S.A., the average result works out at 12½ cwt. In South America, British Guiana is credited with from 16 to 17 cwt.; while in certain parts of Brazil, results up to 25 cwt. on irrigated land have been recorded. Dry hill cultivation in Brazil shows as high a result as 18 cwt. an acre, which is exceptionally good, since, as a rule, the difference between dry and irrigated cultivation shows a considerably greater difference in yield.

CHAPTER VII

TRANSPORT AND SUPPLY

HAVING reviewed the conditions under which bulk supplies are produced, the next point we have to consider is the transport of the grain to the big milling or shipping centres. Before the grain leaves the district in which it is threshed, it is usually sold by the cultivator direct from the threshing floor to local paddy merchants, or to brokers acting on behalf of large rice merchants or millers as the case may be.

Although the quantity of paddy milled and shipped in bulk is a relatively small proportion of the world's total production, the former may, and frequently does, amount to two or three million tons per annum in each of the three main exporting countries, Burma, Siam and Indo-China.

As the quantity destined for export has to be milled within a few months, it will be seen that the question of bulk handling and transport is important.

Whether the grain is to be distributed over considerable tracts of country as, for example, in Bengal, Behar, Orissa, or Madras, to be used for feeding a great but relatively local native population ; or whether it is to be carted to the nearest railway or river system and thence conveyed by train or boat to its ultimate port of shipment, the cultivator can rarely afford to bother his head about it once threshing operations are completed.

The agent or broker is in a different position, his business being to provide bulk supplies to his principals in the milling and shipping centres. He contracts for the supply of so much grain at a stipulated price for

100 baskets of paddy, the usual weight of a basket being approximately 46 lb. He goes round among the cultivators to see at what price—lower than that at which he has contracted to supply—he can secure the requisite quantity. The cultivator is usually a poor man and cannot himself afford to hold up any quantity of grain for any length of time, with the result that, after the usual Oriental haggling has taken place, the broker gets his rice for re-sale at a profit and his brokerage from the purchaser besides. He then arranges for the conveyance of the grain from the farms, to rail or river as may be most convenient. Transport by road in the East is invariably slow, and the load which it is possible to transport by bullock cart is relatively small.

In Burma and Siam, paddy is rarely conveyed in bags because bagging is costly ; where conveyed by boat it is invariably transported in bulk. On certain railways it is also handled in bulk ; but there are lines where, in order to expedite transport and handling, the railway authorities insist on paddy being delivered to them in bags. In French Indo-China, on the other hand, nearly all the paddy which finds its way to the coast for export is brought down in bags, and the rapidity with which the ordinary Chinese coolie can handle sacks weighing anywhere from 150 to 225 lb., requires to be seen in order to be appreciated.

Owing to the wonderful natural system of water-ways in these vast exporting countries, river transport is the most convenient and cheapest method of bringing up-country products to the consumer ; one may see boat load after boat load coming down stream by day and night during the two or three months following harvesting operations. Owing to the extraordinary river network, this system of transport taps huge areas of cultivated land, and it is a simple matter to fill up a boat load of paddy at almost any convenient point on a river bank.

It is otherwise as regards railways ; stations are much less frequent than in this country, and the railway may be a single line, several hundred miles in length. In such cases the grain is brought to the railway in bullock carts, from which it is dumped beside the line in ever increasing volume to await the first available train. When it has arrived at its destination it is taken in hand by gangs of coolies, who unload the grain and either carry it into the go-downs or great sheds prepared for its reception, or simply dump it on the bund, or quay, until such time as it can be dealt with by the purchaser or shipper.

When one sees the huge dumps of paddy alongside up-country railway in Burma, or the vast stacks of bagged rice—rising to many feet in height—lining the quays in Indo-China, one cannot help feeling that surely some more efficient and less costly method of handling, loading, discharging, and storing, might be devised and adopted by those directing and controlling this vast trade. Prejudice and custom are difficult to overcome ; the native labourer has for generations been accustomed to handling grain—whether in bulk or in bag—with reasonable expedition. The cost of installing bulk grain-handling plant has hitherto been considered too high compared with coolie hire. Natives are most conservative and dislike innovations, particularly if they think that these are likely to deprive some of them of their occupation.

If for any reason the usual gang of coolies employed is disbanded, it is often only with the greatest difficulty that sufficient labour can again be recruited. At the same time, and judging from considerable opportunities for observation in many Eastern countries, the author

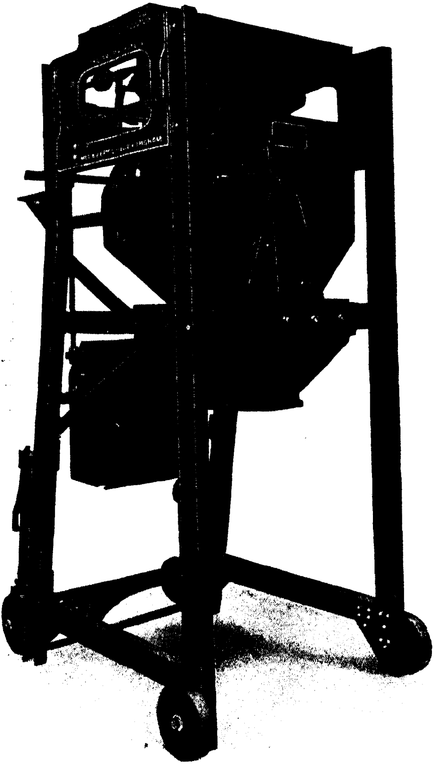


Fig. 13

AUTOMATIC RECORDING WEIGHING MACHINE

believes that the time is not far distant when complete mechanical appliances will require to be installed, for handling the huge volumes of grain dealt with daily during the season, together with reliable automatic and recording weighing machines. (*See* Fig. 13.)

Having now considered in a general way the cultivation and supply of the grain, and before proceeding to examine in detail the broad question of preparing the rice for export in bulk, let us look for a few moments at the manner in which rice is treated by the small native cultivator or local miller.

CHAPTER VIII

NATIVE PREPARATION OF RICE FOR FOOD

WE have seen that the actual rice grain consists of a starchy kernel coated with a closely adhering cuticle or skin, which in turn is protected by an outer covering of husk. The wants of primitive man are few, and provided the hard outer husk is removed, he is content. While this husk is abrasive and injurious as food, the immediately underlying cuticle contains most of the wholesome and nourishing constituents of the grain.

The native problem, therefore, is to remove the husk only, and this is done by very primitive methods.

The threshed grain, still in the husk, is poured into any convenient receptacle, in which it is pounded by wooden beaters or pestles until the husk is split off and the kernels are exposed. (*See* Fig. 14.)

This pounding is usually done in one of three ways. The most common method is to take a pole of some 6 or 8 ft. in length and 3 or 4 in. in diameter, at the end of which is attached a block of wood, sometimes protected against wear by an iron plate. Working usually in couples, the natives each seize a pole, raise them vertically to a height of some 18 in., and bring them down smartly on the heap of grain. This is repeated time after time, till all the grains are shelled.

In order to lighten the labour of this operation, the poles often consist of bamboos, which are, moreover, smooth to the hand.

The second method is similar except that, instead of operating a series of vertical poles by hand, one or more horizontal planks of wood are employed by the simple

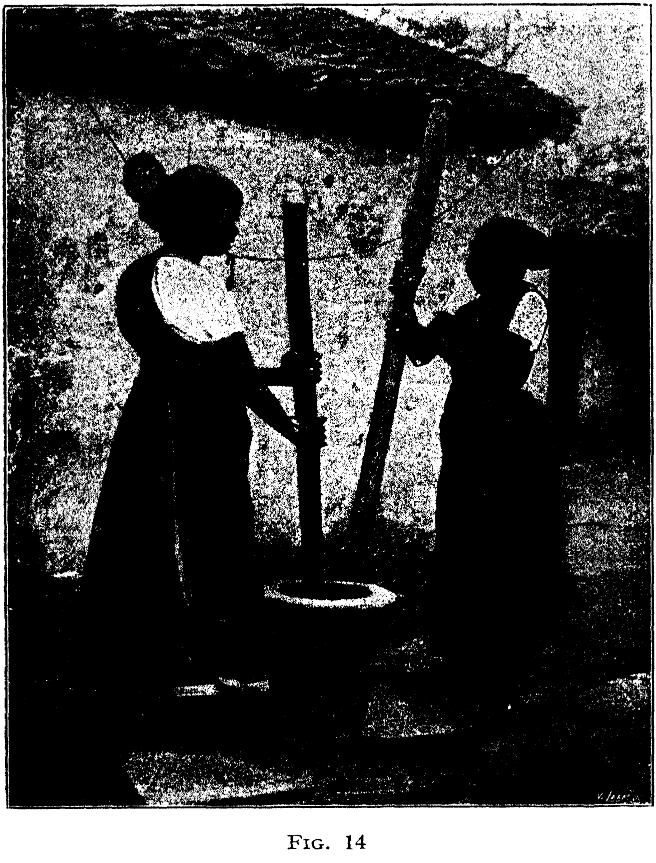


FIG. 14

NATIVES POUNDING RICE

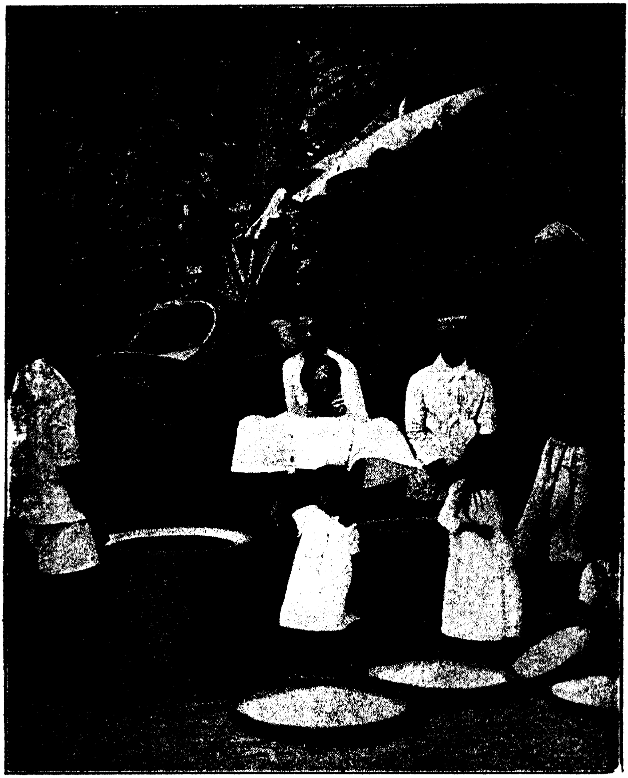


FIG. 15

CLEANING RICE AT MANILA

method of pivoting them after the manner of a child's see-saw. On the underside at one end of the plank a block of wood is fixed to act as a pestle, while a man or woman alternately stands on and releases the other end of the see-saw, so that the pestle is alternately raised out of, and then falls back into, the mass of the grain.

The third method consists simply in beating out the kernel by the use of heavy wooden mallets; the "anvil" consists of a good-sized block of hard wood, or the stump of a tree, and on this the paddy is hammered until the grain gives up its kernel. (*See* Fig. 15.)

Variants of these methods are adapted to be operated by buffaloes or by crude native water-wheels, through suitable gearing, but the action is the same in all cases. It is remarkable how the grains resist this somewhat drastic treatment and how few are damaged by it. A grain of rice is remarkably tough, and after careful harvesting and natural drying it will stand fairly hard usage.

The husk having been removed from the kernel by pounding, both are placed on large trays made of split bamboo. Then follows the natural winnowing process which is a particularly graceful operation to watch. Taking such a tray with a thin layer of grain and husk on it, the operator, skilfully and with a quick motion, throws the whole contents of the tray several feet into the air. This is done when a breeze—however slight—is available: the breeze carries away the light husk and dust, while the heavier solid grains are caught again on the tray. The process is repeated several times until all husk and impurities are thrown off, and the pure grain is left.

As it is not always possible to winnow out of doors in this fashion, ordinary winnowers, such as are seen in many barns in this country, are commonly used.

Fig. 16

WINNOWING MACHINE IN JAPAN

These winnowing fans are made sufficiently light to be worked by hand, either by women or children, and will remove the husk more expeditiously than can be done by the method just described.

Many native Indian races do not treat the rice in its raw state—in other words, the paddy is subjected to a special process before shelling.

This process is termed *parboiling*, and has four interesting results: the grain shells much more readily, it is rendered tougher and less susceptible to breakage, it keeps better after milling and, finally, its consumption as food seems to prevent—in the consumer—the occurrence of a serious disease known as Beri-beri, with which we shall deal later.

The parboiling process will also be described in our next chapter, when we discuss mechanical milling processes.

CHAPTER IX

MECHANICAL MILLING AND PREPARATION OF RICE IN BULK

OUT of the enormous total of *cleaned* rice produced every year throughout the world, by far the major portion is milled by primitive manual methods or by the simplest possible machinery. The reports of the Imperial Institute put the world's exported surplus of rice at roughly 5,000,000 tons, most of which is milled by more or less modern mechanical appliances. In addition, however, there is a considerable output of mechanically milled rice, which is not exported from the country of origin but is consumed locally. During the last fifteen or twenty years there has been a considerable increase in the number of small mills placed close to the source of supply.

Moreover, co-operative milling is becoming more common. A small group of natives decide to erect a small though none the less complete mill [1]; the surrounding native farmers bring in their threshed grain, and the mill is thus kept fully occupied in treating small quantities which in the aggregate constitute a fair load. The milling co-operators recoup themselves either by charging so much for 100 baskets of paddy milled, or by returning the milled rice only, retaining the small broken and offals as payment in kind. Alternatively, the milling group may also be traders, buying the paddy from a number of small cultivators in the surrounding district, and disposing of the finished rice to brokers for re-sale.

Whether we consider milling on this basis, or as carried out in bulk in close proximity to the big Eastern shipping ports of Burma, Siam, or Indo-China, the principles of milling are essentially the same. The various processes are identical, and the machines used differ only in size and in number employed.

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[1] *See* Fig. 17.

Let us consider these processes in detail and coincidentally study the machinery used in carrying them out.

1. **Paddy Cleaning.** From the account given earlier of the method of collecting, stacking, and transporting the grain received from widely spread areas, it will be obvious that a considerable amount of impurity must first be got rid of. The very circumstances of threshing on open ground with men and women, children and cattle, engaged on the operation, contribute to the admixture of all sorts of foreign matter. Little care is exercised in collecting the grain from the threshing floor, so that a considerable amount of rubbish is also collected. It is therefore not surprising that considerable cleaning plant has generally to be installed to remove this extraneous rubbish from the paddy, before the milling process.

For rough cleaning, a simple form of riddle is used to screen out the major impurities, which are larger than the grains of paddy, as well as to separate the smaller foreign matter such as seeds, sand, and dust. This is done by means of perforated steel screens carried in wooden frames arranged in the form of shallow drawers—one above another—which frames are removable, and can be readily interchanged with others containing screens of larger or smaller perforation as may be required.

A glance at the catalogues issued by makers of grain-cleaning plant, will show clearly that the sieve frames are contained in a wooden box supported at each corner

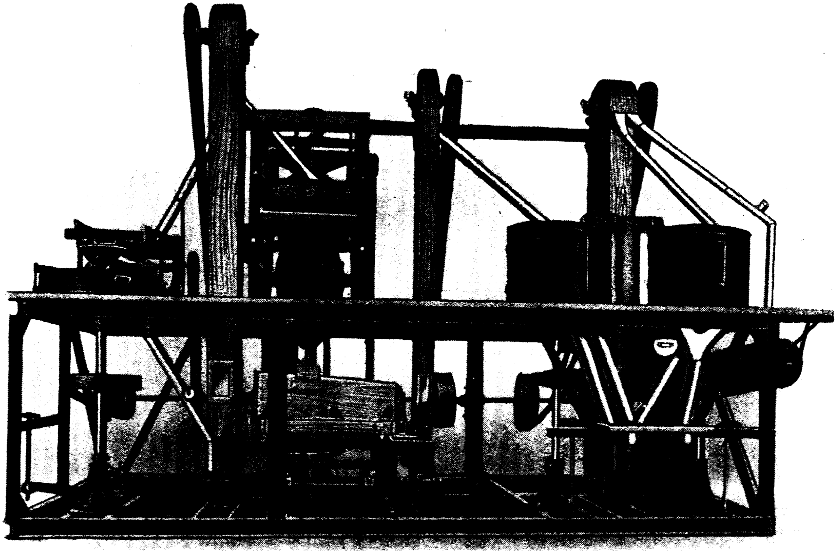


FIG. 17

COMPLETE SELF-CONTAINED LL

by a vertical thin flat bar acting as a spring ; a quick reciprocating motion is imparted to the box by an eccentric carried on a horizontal spindle, so that a rapid sieving action is set up.

While this machine removes heavier impurities, it does not deal with the dust which is freely liberated during the sieving process. It is common practice to arrange a large hood over the machine, the apex of the hood being connected by a pipe to a suction fan, so that the dust may be drawn off and discharged to some convenient point outside the mill.

In modern mills the receiving separator is the proper machine to install ; it is used regularly in flour mills for exactly the same purpose as in rice mills, and has the merit of combining in a convenient, accessible, and efficient manner, the double functions of sieving and aspirating. (*See* Fig. 18.)

The grain is fed in on a wide stream, and as this stream passes through a suitable channel it is subjected to a current of air moving with sufficient velocity to extract all light impurities, the heavier matter falling on the first sieve, which extracts fibrous material such as string, straws, etc. The balance of the material is then led on to a second finer sieve, which removes stones and matter of that sort ; and the grain then passes over a third, still finer, sieve, which retains the paddy while extracting sand and small seeds such as millet or cockle. The grain is then subjected to further aspiration, which removes any dead or weevil-infested grain, husk, or similar matter.

The paddy is discharged from this machine in a thoroughly clean condition ready for the next process.

It is desirable that, wherever conditions permit, the paddy-cleaning process should be screened off from the rest of the mill as the dust is most objectionable.

2. **Shelling or Hulling.** The clean paddy is next delivered to the shellers or hullers, the function of which is to remove the husk from the kernel contained therein.

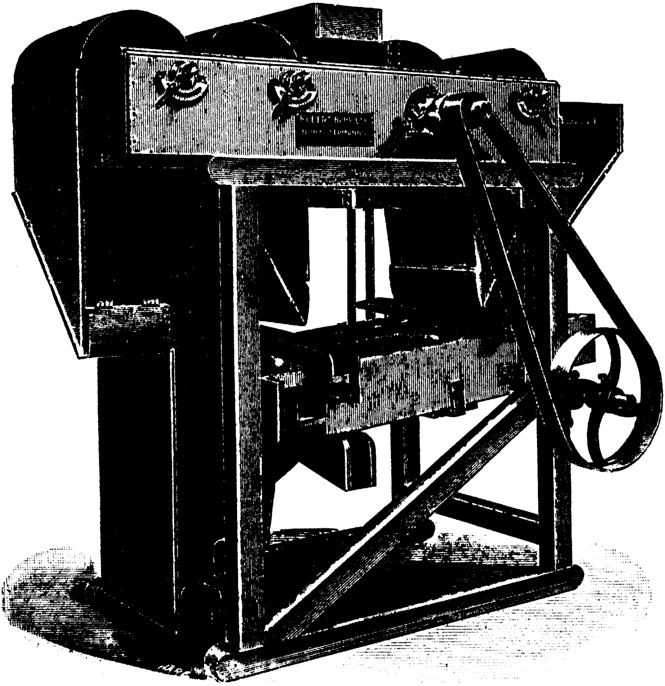


FIG. 18

PADDY-RECEIVING SEPARATOR

At this point we must consider the possible introduction of a machine for removing the beards or awns from the paddy grains. Reference has already been made to this objectionable feature of some rices. Not only does it prevent the proper shelling of the paddy, but if bearded grains are permitted to pass to further milling processes, these are most seriously impeded.

There are various types of machine in use ; in some the grain is passed between a rapidly revolving conical surface of hard material and a strong stationary wire-cloth casing, the space between being such as to give free passage to the grain itself but not to the grain plus the beard, which is effectively broken off. In other machines, two metallic cylinders are arranged round a common axis ; the external cylinder is fixed and is provided internally with spikes or projections ; the internal cylinder is fitted externally with similar spikes, and as this latter cylinder revolves, the bearded grain is caught between the fixed and the revolving spikes, with the result that the beards are broken off but the paddy passes undamaged.

Another important auxiliary which deserves mention at this point is the *Magnetic Separator.* It is employed for removing from the grain any bits of iron or steel, such as nails, or loose bolts or nuts, the passage of which through subsequent machinery might result either in serious damage to that machinery, or in fire risks through sparking.

Two types of machine are commonly used, the one having permanent magnets arranged in a frame, over which the paddy passes in a uniform thin stream. The other is fitted with metallic surfaces, which can be rendered magnetic by connecting the apparatus to an ordinary electric lighting cable. It is also important to see that the cleaned grain is properly and systematically weighed at this point. In the larger mills, automatic recording weighing machines should be installed. (*See* Fig. 13.)

The shelling of rice has passed through interesting evolutions, and various devices have been tried with greater or less success. A modification of the old " mortar and pestle " system is still used in some otherwise relatively modern mills in Italy and Spain. It is identical in principle with the hand-operated pounding system already described under native methods, the only difference being that now the pestle is a steel rod fitted with tappets, working in a guide, and actuated by a double-armed curved steel cam fixed on a rotating shaft, similar to the stamp batteries used for crushing gold-bearing quartz. The base of the " pile " drops into an ovoid receptacle—probably of cast iron—and the rice is hulled as already described.

A machine in vogue in the United States fifty or more years ago consisted of two cylinders of wood, the outer one revolving slowly in one direction while an inner solid cylinder revolved rapidly in a contrary direction. Each cylinder had keys or bars projecting from its working surface, and between these the grains of paddy were rubbed until the husk was removed.

To this day, a simple machine in almost universal use, which had its origin in the U.S.A., is constructed in the form of an outer stationary cylindrical casing in which a small cast-iron cylinder, fitted with projecting bars or strips, revolves at a high rate of speed, effectively shelling the paddy. These methods, while simple and inexpensive to install and operate, are apt to do considerable damage to the grain.

The old millstone has been used for shelling rice for generations, and by common consent the same principle is accepted as the best and most economical method of hulling rice to-day. The stones are now replaced by two carefully constructed, balanced, cast-iron discs, of which the upper one is preferably stationary, while the lower one revolves. The upper disc forms the top of a circular dust-proof box ; this disc has a large inlet hole in the centre, and over this a feeding hopper is placed to regulate the supply of clean paddy and to discharge it at a suitable rate between the two discs, the surfaces of which are covered with a mixture of emery and cement. The space between these discs is only such as to allow a thin stream of paddy to pass, and in this passage the husk is removed from the kernel by the cracking action of the hard surfaces.

The husk is so extremely abrasive that even the exceptionally hard milling surfaces of the discs become rapidly grooved, and require to be trued up from time to time with a diamond point. The lower or revolving disc is fixed to a steel spindle carried in an adjustable bearing so that, as the disc surfaces wear, the correct distance between them may be maintained. In small mills these hullers or shellers are usually carried on a low iron framework which makes them self-supporting ; but in large mills, dealing with several hundred tons of paddy a day, they are placed on the first floor, which is reinforced by substantial columns carried up from the ground floor. (*See* Figs. 19 and 20.)

A variant of this type of double-disc huller with artificial faces consists of a machine in which the driving spindle or shaft is placed in a horizontal instead of in a vertical position, the discs running on edge, as it were ; the action is the same in either case.

Owing to the unavoidable difference in the size of rice grains even from the same source, there is always a certain proportion which is not shelled during this process. If the discs are set too closely together there is risk of breaking the rice ; if, on the other hand, the discs are spaced too far apart, an unduly high proportion of grains will pass through unshelled. The proper relation is obviously a matter of adjustment.

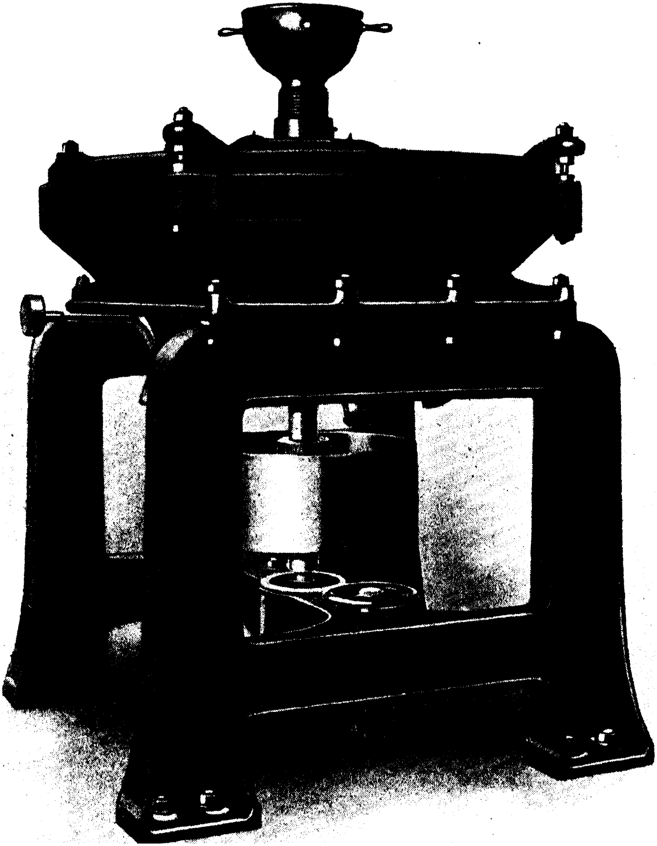


FIG. 19

DISC HULLER OR SHELLER (SELF-CONTAINED)

The material discharged from the hullers consists of four products—

(*a*) Shelled rice.
(*b*) Rice which has escaped shelling.
(*c*) Husk.
(*d*) Dust, and small broken grain.

We will now consider how these four products are dealt with.

3. **Removal of Broken Grain and Husk by Sieving and Fanning.** The mixed product of the hullers is now elevated to the next process, which is in effect a multiple one, carried out by two individual machines, although these are usually combined in one unit for the sake of convenience.

The four products are first of all passed over a reciprocating sieve placed above and usually supported upon the framework of an aspirator or winnower, with which we shall presently deal.

Like the sieve described in the paddy-cleaning process, we have a simple rectangular framework fitted with a screen of perforated steel, which not only serves to extract small particles of broken rice, broken husk, and dust, but also fulfils a useful function by distributing the rest of the product over the inlet hopper of the lower part of this machine in a uniform broad stream, thus inducing more satisfactory treatment.

This lower part of the machine which has to effect removal of the husk consists of a wooden chamber, the internal construction of which is specially arranged, according to whether the husk is to be taken out by aspiration or by blowing. Opinions differ as to the relative merits of one system compared with the other ; the object of both is the same—to take *all* the husk and any dead grain out of the rice, but to avoid the removal of any live grain whatsoever. In the case of winnowing

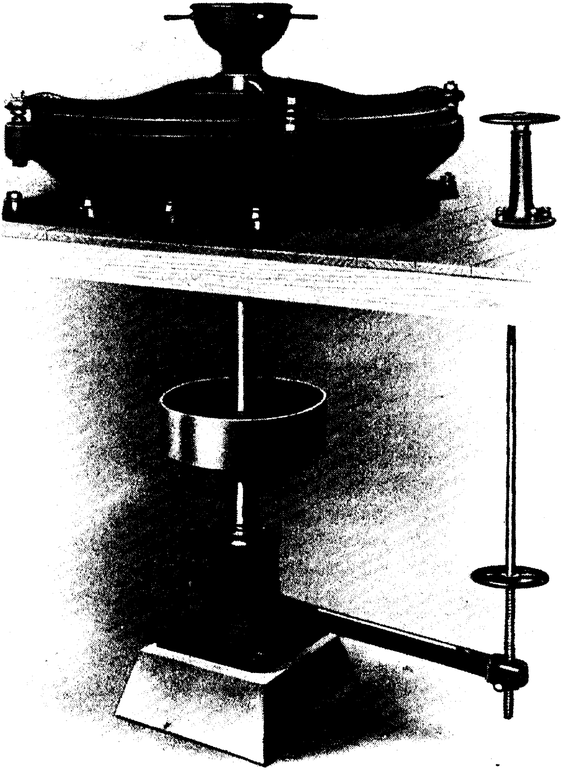


Fig. 20

SHELLER OR HULLER FOR LARGER MILLS

or blowing fans the husk is driven through the machine and out of the mill proper, into an annexe commonly termed the husk house, where the husk is collected to be used as fuel. If, on the other hand, the machine is designed to operate by aspiration, it is not necessary to have a husk house, although accommodation must be provided somewhere for this material.

The husk being eliminated, there remain still two main products as well as by-products—clean shelled rice, and clean but still unshelled paddy. The by-products consist of inferior, immature, and larger broken grains, and these are automatically discharged at this point to be used for live-stock feed in the case of small mills, or for subsequent re-treatment if the mill be large enough to make such treatment a paying proposition.

We are concerned at present with the whole shelled and the remaining unshelled grain, and the next problem is how to remove the latter from the former. This is effected by mechanical separation.

4. **The Separation of Paddy from Rice.** The original method of separation is effected by the employment of rotary separators. The usual type has three trays, placed one above another and contained in a common framework which is invariably hung from above. The necessary rotary motion is imparted by a balanced crank, placed either above or below the machine and actuated by belting or gearing as may be most convenient.

As is customary with all classes of sieves used in milling processes, the perforated trays can be easily and quickly removed for repairs, for cleaning, or to allow of the substitution of other trays having different perforations.

The upper trays remove the paddy, and the "throughs" from the bottom tray are clean-shelled rice or what is known largely throughout the East as " Loonzain " or

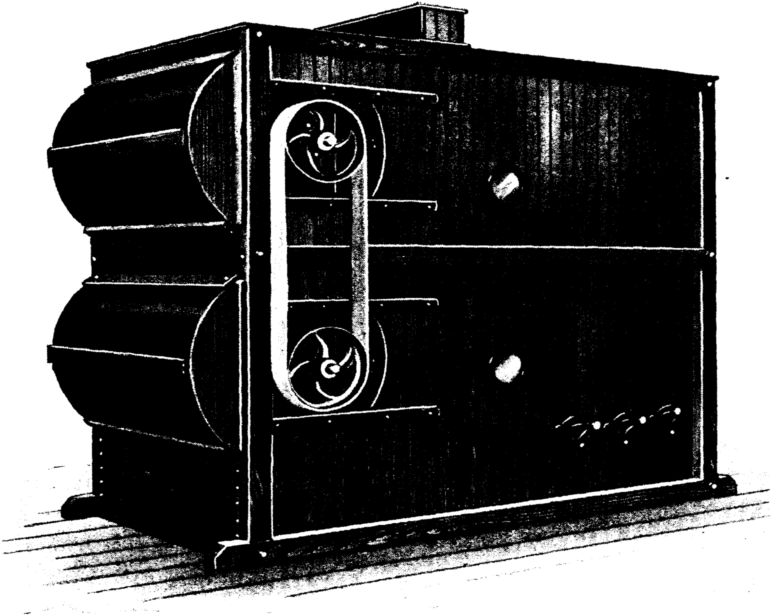


FIG. 21

DOUBLE WINNOWING FAN

"brown rice." A combination of such trays in the form of a plansifter, as employed in flour milling, is now commonly used to deal with bulk separation of rice.

The machine which now finds general acceptance is the well-known compartment separator or eliminator, one of the cleverest machines yet introduced into milling processes. It is more or less identical with the dry stoner, which is well known in the flour and oat milling industries, but modifications have been introduced to render it more effective when dealing with rice. This machine merits a somewhat full description. In the simple single-tray form it consists of a table having a smooth metallic surface, generally horizontal, but with a slight tilt which can be varied within narrow limits.

If such a table is subjected to rapidly repeated horizontal movement, the mass of grain will be moved back and forward at each oscillation and, on account of the lateral inclination or tilt, will ultimately move down that inclination and fall to the floor. The shelled grains, being denser than the paddy grains, size for size, and also smoother, will travel more quickly than the latter.

If this movement is suddenly interrupted by obstructions placed on the smooth surface of the table, the direction of movement of the mixed grain is changed. These obstructions are provided in the form of sheet-metal triangles, disposed in such a manner that while the shelled grains merely suffer retardation of their downward movement, the less dense and rougher grains of paddy begin to *ascend* the incline.

The usual commercial machines vary in capacity from 500 to 5,000 lb. of rice an hour, but their capacity can be conveniently increased by placing two machines *vis-à-vis* operated by a common driving shaft (Fig. 22).

The final separation with which we are for the moment concerned having thus been effected, our two products

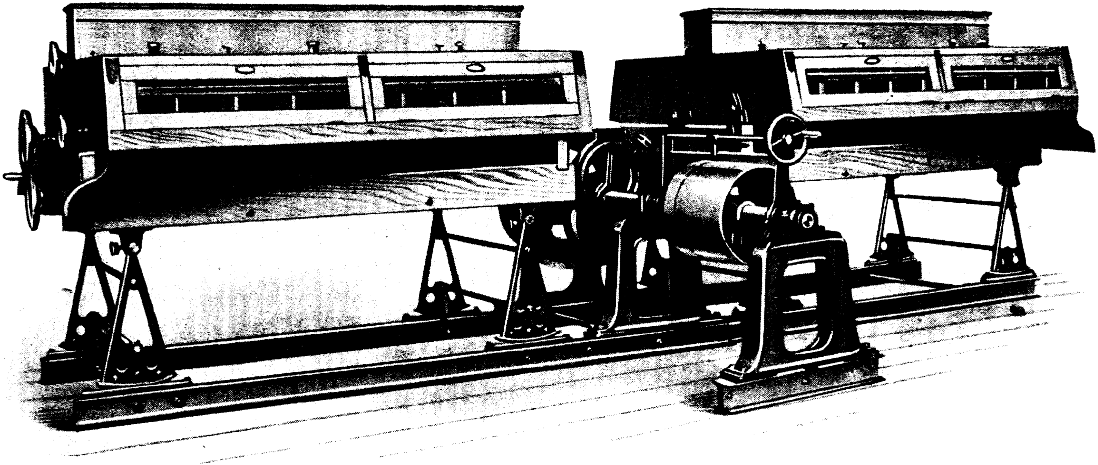


FIG. 22

COMPARTMENT SEPARATORS

are pure paddy and pure " loonzain," the former of which is returned to the hullers. In the case of large mills where many hullers are installed, it is usual, and in any case desirable, to earmark several of these machines for dealing only with this returned paddy. This obviates the readjustment of the main machines, with consequent interruption of the main milling flow.

A generation or two ago, it was not usual to finish rice in the East to anything like the same degree as that to which it is now finished, and it was customary to ship rice in a partially milled condition known as " five-part cargo rice." This was the product of the hullers or shellers from which the husk had been winnowed and the " rough " broken grain and meal removed; but the shelled and unshelled grains had not been completely separated, and 20 per cent of the latter were included and shipped with the forme. Hence, the name of " five-part cargo."

At one time there was a lively milling industry in this country, which dealt with five-part rice, separating out and shelling the still unhusked grain, and whitening the loonzain or pure husked rice.

The development of milling in the East as well as in European ports has unfortunately reduced the rice-milling industry in this country to vanishing point.

We have dealt with the principal machines in what is usually termed the " Cargo " mill, although there is the usual complement of elevators and conveyors and, of course, the transmission necessary to operate both main and subsidiary machines.

We spoke a little while ago, under *Husk Aspiration*, of the treatment, in a large mill, of the secondary products from the aspirating or winnowing fans, as well as from the sieves over these fans. These products may be passed over cylindrical separators known as reels, to take out the small broken " rough " rice and to separate this from the accompanying dust. The former may be passed over a secondary set of winnowers or aspirators, being duplicates of the main machines of that series, in order that no whole or large broken grains by any chance escape along with a second grade product commanding only a lower market price. The final offals are usually passed over a third and smaller aspirating machine in order to cleanse them from meal or dust. The admixture of first with second, or second with third grade products is to be avoided, as the presence of a lower grade product in any final sample simply reduces the market value of that sample.

5. **White Rice Milling.** Although there may not be any clearly marked structural division between the cargo rice and the white rice sides of a mill, the processes themselves are quite well defined.

We come now to the most critical and important milling process.

6. **Pearling or Whitening of the Clean Loonzain or Brown Rice.** We have learnt at an earlier stage that, below the easily removable husk, and surrounding the starchy kernel of the rice, there is a closely adhering fine skin or cuticle which can only be removed from the kernel by attrition. If the surface of a grain of rice be carefully examined after being hulled, it will be noticed that not only is the kernel slightly corrugated in a lengthwise direction, but also, that the cuticle adheres equally in the depressions as well as on the ridges of the corrugations.

Moreover, as we have seen, this cuticle varies from a creamy or pale yellow to a dark mahogany red colour, so that much more severe milling is required to produce " white " rice in the latter than in the former case.

As in hulling, so also in pearling, various devices have been tried in order to accomplish this process satisfactorily. The mere hulling or shelling is simply a matter of necessity as the husk cannot be eaten, but pearling or whitening is a refinement of later date and is demanded in the case of all rices consumed in Western countries.

Early records are not very clear, or they have not come under the author's notice ; but in 1819 Lucas and Ewbank installed a plant in which the husk was removed by ordinary millstones and the cuticle was thereafter rubbed off by pounding, exactly as has been referred to in describing native methods.

These people appear to have been troubled by the glutinous nature of some of the rice with which they were experimenting ; in order, therefore, to hasten as well as to improve the whitening process, they re-mixed with the grain a certain amount of loose husk and dust, the whole being pounded together.

It may be of interest to record that, 100 years after the date of these early experiments, the author has seen exactly the same mixing process adopted in native mills in Bengal.

Lucas and Ewbank finished their rice by passing it between two concentric cylinders, one of which was stationary, while the inner one—covered with sheepskin—revolved at some considerable speed.

Another patent was taken out in the early days by Shiel, who, after shelling the paddy between two millstones, one being of wood and the other of natural stone, removed the cuticle by rubbing the shelled grains between two flat boards covered with sheepskin ; but in this case the wool was next the boards and the skin was the abrading agent.

Two other methods were adopted and are still in use, in America and Italy respectively. In the first case the rice is passed between a fixed cast-iron cylinder covered with a perforated steel plate, and a rapidly revolving cast-iron roller, the surface of which is provided with chilled iron ribs. A steel blade is inserted along the centre line of the outer fixed cylinder which is in halves, and is held in such a position by adjustable screws, that there is just room for the grains of rice to pass between the edge of the fixed steel plate and the revolving roller, with the result that the cuticle is ground off between the two.

The other machine to which reference has been made in connection with Italy, consists of a short endless screw mounted on a spindle, the lower end of which is carried on a suitable bearing. This is fixed within a hemispherical or ovoid vessel which may be either of cast iron or other suitable material. The upper part of the spindle is carried by bearings above and outside the vessel and is rapidly rotated by any convenient means. The rice is simply turned over and over within the vessel by the continuous action of the screw, and the only attrition to which the grain is subjected is that caused by the friction of the grains, one against another, combined with such rubbing effect as may result from the pressure of the grain *plus* the action of the screw, against the sides of the vessel.

The machine which is now universally adopted for whitening large quantities of rice is the *Pearling Cone,* which up to the present time has entirely superseded all other methods.

A comparative study of the design adopted by the principal makers reveals no outstanding difference except in relatively unimportant details ; the main features are the same and may be described as follows : A truncated cone consisting of an iron body covered with a special mixture of emery (or in certain cases carborundum or similar material) and cement, is mounted on and secured to a vertical steel spindle, the lower end of which is supported by an adjustable footstep bearing. In the earlier days the spindle was prolonged above the cone and was there supported by another bearing carried on a cross-beam. As the growing tendency has been towards shortening the height or length of the cone and increasing its diameter, it has been found possible to place the second bearing immediately below the cone and yet secure sufficient rigidity, without sacrificing continuity of operation.

Immediately surrounding the cone, but leaving an annular space between the two, is a conical screen of woven steel wirecloth, carried on a light iron framework which permits of rapid removal for examination, repairs, or renewal. The whole is enclosed in a sheet-iron casing provided with a central top opening for ventilation, and another opening, fitted with a small regulating hopper, towards the outer edge of the machine, into which the grain is fed.

As the cone revolves at a high rate of speed within the fixed wirecloth crib. the rice is subjected to rapid and intensive attrition between the hard emery and the rough surface of the steel wirecloth, with the result that the cuticle is rapidly rubbed off and the white kernel is exposed. In order to prevent the rice from being whirled round with the cone, it is now universal practice to insert substantial bars of specially prepared india-rubber, at intervals round the periphery of the crib. These bars project inwards but not sufficiently to come into contact with the cone or they would rapidly be destroyed. They cause the rice to bank up, and momentarily but sufficiently impede the motion of the grain, so that every individual kernel passing through the annular space is acted on between the rubbing surfaces.

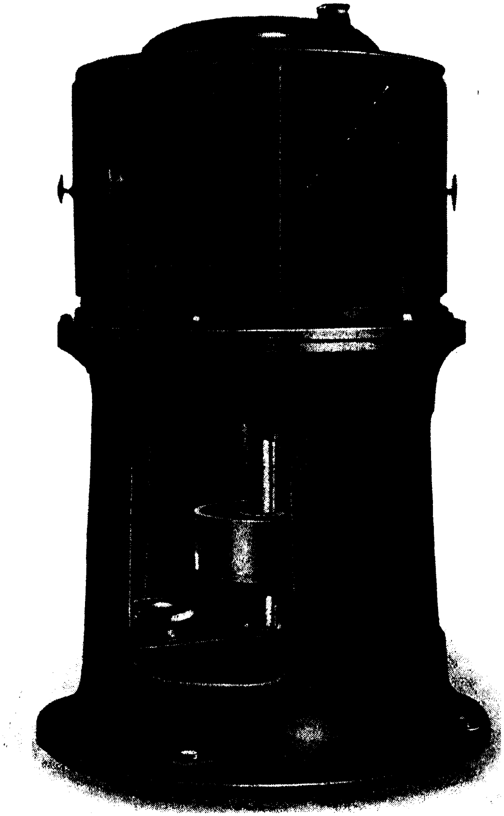


FIG. 23

WHITE RICE PEARLING CONE (SELF-CONTAINED)

The cuticle is reduced by this process to a stone-coloured meal, which escapes through the wirecloth into the annular chamber between the crib and the outer sheet-metal casing. Here it is collected by a circular revolving scraper and discharged through an aperture in the bottom. The rice itself is collected in a central delivery pan arranged round the revolving spindle and discharged where required.

The outer casing is provided with doors of ample size to give access to the interior of the chamber for examination of the wirecloth, and to permit of adjusting the rubber brakes in relation to the cone face as both become worn. The milling process is so intense that by degrees the cone face wears, and it becomes necessary to true it up and then to lower the cone in order to maintain the correct spacing between it and the surrounding crib.

The required degree of whiteness is attained by adjusting the position of the cone, in other words, by altering the width of the annular space between cone and wirecloth. With a cone well raised, the rice may pass through untouched; but, as it is lowered and the annular space is diminished, the milling action is intensified for a given quantity of rice, which is thereby increasingly whitened.

In a well-designed machine, breakage of grain is remarkably small; but it will be obvious that, the whiter the rice is milled, the greater the tendency to breakage becomes. For this reason it is customary, even in small mills, to pass the rice through two (and in larger mills often through three or four) cones in series, so that each succeeding cone removes a little more of the cuticle instead of forcing the pace through one cone only.

The heat generated during this process is considerable; also, the whitened grains of rice become covered with a layer of fine meal. In order to minimize the heat and

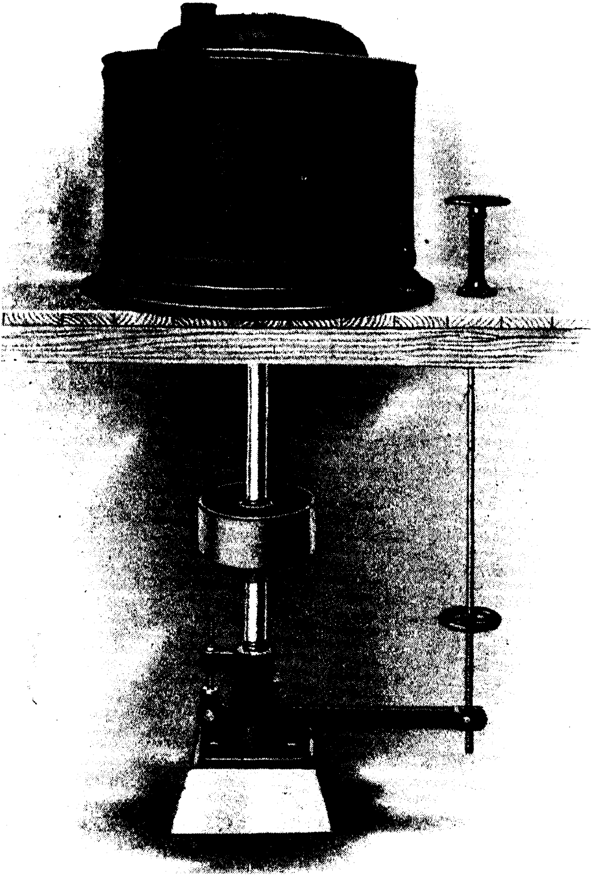


Fig. 24

WHITE RICE PEARLING CONE FOR LARGER MILLS to remove this meal, a current of air is usually blown continuously into the machine by a pressure fan, while an aspirating fan, connected to the outer chamber, assists in maintaining this current.

The method of supporting these machines is the same as that used in the case of the hullers, the smaller machines being carried on a low framework, the larger ones being supported on floor joists or heavy columns.

When it is desired to produce a particularly fine sample of white rice, or if that rice is to be artificially glazed to meet the demands of super-civilization, it is usually subjected to the true " polishing " process.

7. **The Rice Polisher.** Externally, this is not unlike the pearling machine, but the hard emery cone is replaced by one composed of wooden staves covered with strips of sheepskin, felt, or similar material. The surrounding crib is retained, but the heavy wirecloth of the pearler is replaced by one of finer texture so as not to abrade the surface of the grain.

The spindle runs in an adjustable bearing and the settling chamber is ventilated by aspiration only.

In important mills, it is desirable to insert the magnetic separators already described before the pearling and polishing cones, to prevent damage to the wirecloth from the intrusion of foreign metallic substances.

In small, mills the finished rice from the pearling or polishing cones is taken to what is known as a *finishing aspirator*. This machine resembles that used for the removal of husk from the shelled rice in the cargo mill, except in so far as modifications are required to remove from the surface of the grain any particles of meal or dust. It is usually fitted with a separator having a sufficient number of screens to permit of three products being separated out, namely, whole, large broken, and small broken, white rice. From this aspirator the three products pass automatically to bags, which are placed in readiness for sacking-off the finished products.

8. The Further Treatment of Pearled Rice in Large Mills. When milling several hundred tons of rice a day to a high degree of finish, the recovery and proper classification of the broken grain is a matter of great importance.

There are several classifications of so-called whole rice, each of which permits the inclusion of a definite proportion of large broken rice, the small broken being ruled out. No. 1 and No. 2 Europe Qualities are well recognized trade terms ; so are S.Q., Straits Quality, and Specials. In the Far East we have No. 1 and No. 2 Japan Quality, and so on ; in addition, some of the big milling companies have their own trade marks for finished rice. All of these permit a certain proportion of large broken grain to be included in the final product, varying from 40 per cent in the lower grades, to 10 per cent in the higher grades. The rejected brokens, or *coodies*, as they are usually termed, are graded down into numerous sizes, each having its definite market value.

Large mills usually subject the whitened rice to further treatment in compartment separators, to extract any remaining unshelled grains ; this rice is also subjected to further treatment in three-tray separators, or in plan sifters, to secure the retention of whole and large broken grains; while half-grains and smaller sizes are passed through other machines, for classification if desired.

Two machines which are in constant use for this purpose are the *Reel* and the *Trieur cylinder*.

The revolving reel may be circular or hexagonal in section, and is usually constructed with perforated screens carried in removable frames, to permit of rapid renewal, or of alteration to modify classification. The screens must be kept clean and free of rice grains, which would soon choke the meshes, and various devices are fitted for this purpose.

The *Trieurs* consist of accurately cylindrical metal barrels composed of either rolled zinc or steel sheets, having a number of small recesses drilled or stamped in the inner surface. The efficiency of this machine depends on the accuracy of these recesses, but it is inadvisable to load them heavily if accuracy of separation is required. A longitudinal screw conveyor and a specially designed trough fitted inside the cylinders, can be adjusted to vary the degree of separation within reasonable limits. By working several pairs of these cylinders—suitably mounted on a framework—in parallel, considerable quantities of grain can be handled.

It is impossible to lay down any hard and fast rule for subsidiary classification ; it must be governed by market requirements as to quantity and quality, and ample provision should be made accordingly.

9. **The Production of Rice Flour.** Although the manufacture of rice flour is not, strictly, a rice-milling process, it is carried out in some of the European white rice mills.

For the production of rice flour, the broken resulting from the final whitening or polishing process is generally suitable. Grinding may be effected by ordinary millstones, which will produce an excellent sample, or by the usual type of roller mill used in the production of wheat flour. The product is subjected to practically the same refining processes as in the case of flour milling, to meet the requirements of the market, which may be for culinary and baking purposes, or for the preparation of patent foods.

10. **The Treatment of Rice Meal.** We must retrace our steps for a moment to the pearling process, where

we saw that the outer cuticle, together with the germ, was removed from the rice kernel by attrition in the form of meal.

In small mills the further treatment of this meal is not commercially profitable ; it is a valuable food for certain animals, notably, for pigs, as it contains a considerable amount of oil besides other nourishing constituents.

Experiments have been carried out on a large scale for the recovery of this oil, which may be as much as 18 per cent of the meal ; but the cost of the plant necessary for dealing with this by the solvent process, which so far seems to be the only suitable method, renders such recovery commercially impossible.

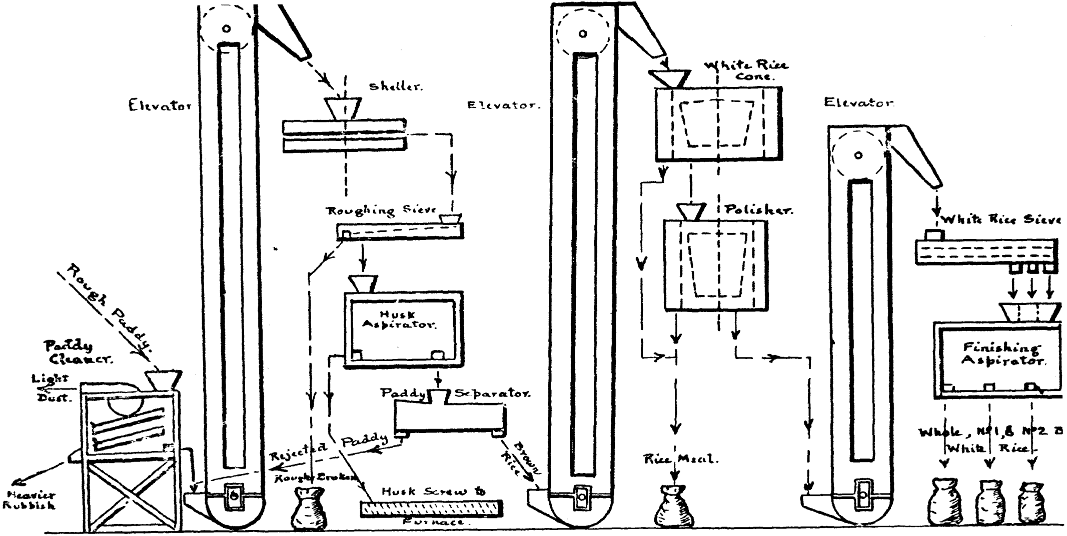
In some countries, notably, in Italy, what is known as " Oiled Rice " is marketed ; the rice is whitened by the usual processes already described, and subsequently treated by the intimate admixture of some fine odourless oil, which imparts a certain lustre to the kernel. This can be effected by re-mixing the white rice with the oil-bearing meal, which can still be sold afterwards for animal food.

The treatment to which meal is subjected in large mills has for its object the recovery of the small broken rice which is inevitably produced in the pearling and polishing processes. While the major portion of the broken grain will pass through these machines along with the whole rice, there is always a proportion of small broken, with occasional whole small grains, which is forced through the wirecloth and deposited in the settling chamber along with the meal ; the recovery of such broken rice is commercially desirable. The meal is therefore passed through *Centrifugal Meal-dressing Machines*, which permit the passage of the fine meal but retain any particles of rice, however small. These are then taken to suitable grading reels, classified, aspirated, and passed on to join the corresponding small broken grain which has already been separated out of the whole rice, the meal being conveyed to its own particular bagging-off point.

We have still to deal with the very fine meal flour or dust which is extracted from the cone-settling chamber by the aspirating fans already referred to. The discharge pipes from these fans are connected up to a *Tubular Dust Collector.* This usually consists of a rectangular receiving chamber in which the air expands, and from which it passes through a series of flexible cloth tubes, depositing on its way the fine meal with which it is charged. The tubes terminate in a second rectangular box, in which the fine meal is deposited, and from which it is collected by a worm conveyor, and taken to the bagging-off point.

While dealing with the subject of meal and dust collection, we must not omit reference to that useful appliance employed alike in large and in small mills—the *Cyclone Dust Collector.* Its function is to separate light, fine particles of heavier-than-air material from the air in which they are for the time being carried. It is used in conjunction with the aspirators to which reference has already been made, as it is the most convenient receptacle into which the current of air from the aspirator fan can be led. The solid matter trickles out from the lower end of the cyclone, to be collected or discarded as required. In small mills the cyclone takes the place of the tubular dust collector, as a receptacle for the air and meal exhausted from the pearling cones.

11. Having dealt with the milling processes essential to the production of finished white rice, and before considering artificial treatment for special purposes, we



—DIAGRAM OF SIMPLE RICE MILL.—

— Shewing Sequence of the Principal Machines. —

FIG. 25

can appropriately consider the products which the foregoing processes yield.

Leaving out of account the "Cargo rice" already mentioned, and neglecting sub-divisions of various sizes of broken white rice, we may reduce the main products to five in number, viz.: finished white rice, white broken rice, white meal, rough broken rice, and husk.

All modern mills keep careful records of their milling results day by day, comparing these season by season. "Out-turn," as it is usually termed, is the proportion of certain marketable products obtained from a defined quantity of paddy, usually 100 baskets, each of 46 lb. weight. A fair average outturn aimed at is the production of 3,400 lb. of products per 4,600 lb. of paddy milled, in other words, an out-turn of 73.9 per cent.

This result should be sought, whatever the grade of white rice produced; because it includes all marketable products, but excludes husk and low-grade dust and rubbish. All products should be accurately weighed and recorded.

To make our meaning clear, let us take two typical returns from Burma, one termed "No. 2 Europe" quality containing 25 per cent of large broken rice, and one of what is known as "specials" containing 38 to 40 per cent of broken.

The out-turns in these two cases are—

	No. 2. Europe.	*Specials.*
Whole Rice	44·82	60·00
White Broken. . . .	20·50	7·23
White Meal	8·23	4·46
Rough Broken . . .	0·31	1·56
	73·86	73·25
Husk and Dust, by Balance .	26·14	26·75
	100·00	100·00

In the first case, as the whole rice contains a lower proportion of broken than in the second case, the proportion of white broken bagged off as such is higher than in the second case; while, for the same reason, the whole rice constitutes a lower percentage of the total.

Similarly, as No. 2 Europe is milled to a higher degree of whiteness, the percentage of white meal is higher than in the case of "specials," which is a lower-grade product.

Out-turns are generally stated in terms of baskets, but these must not be confounded with each other. While a basket of paddy weighs 46 lb., a basket of rice weighs 75 lb. In one of the two cases given above, the out-turn on No. 2 Europe is thus 27·19, being 27·19 baskets (of 75 lb. each) for 100 baskets (of 46 lb. each) of paddy milled; in the second case the out-turn is 36·71 baskets for 100 of paddy.

The proportion of husk varies, but is usually calculated at 20 per cent, although as little as 17 and 18 per cent have been recorded. If we assume a marketable recovery of 73·9 per cent and a husk recovery of 20 per cent, their remains a figure of 6·1 per cent, which represents low-grade offals, dust, and rubbish.

Before touching on this matter of out-turns, we spoke of special methods of preparing rice for certain markets. Attention has already been called to the preparation of oiled rice, but there are other processes which it will be well to consider now.

12. The Artificial Coating of Rice. It is common practice, not only in Europe but also in many large Eastern mills, to add to the rice a small quantity of ordinary blue, as used in laundries, in order to accentuate the whiteness of the finished product.

The powder is added during the final processes by means of a special mixing machine. It must be added with care and thoroughly mixed with the rice; an overdose will defeat the end in view. Such a small proportion as 1 to 18,000, or say, about 2 oz. of blue to the ton of rice, will give to the dead white surface of certain varieties somewhat of a translucent appearance. Further, this treatment of the grain preserves the finished rice when stored and tends to prevent attacks by insects.

A somewhat bizarre effect once observed by the author was attained by treating the finished white grain with some red pigment which produced the lustrous effect of red coral, a not unpleasing result but one appealing to a limited circle of customers.

The process of artificial *glazing*, or *facing*, is very largely adopted, as this gives to the finished rice a lustre and translucence which it does not naturally possess.

The finished polished rice is placed in a large slowly revolving drum into which is fed a mixture, in certain definite proportions, of talc and glucose. Other mixtures are adopted in different mills, but talc and glucose may be taken as typical ingredients.

Sometimes the rice is lightly steamed before the glucose is added in the form of a syrup ; most millers have their own particular methods, which are the outcome of considerable experience, and they are naturally indisposed to communicate these to others. Samples are withdrawn from the drums until the desired result is attained, after which the rice may again be aspirated, to remove any surplus facing material. The proportions of this material require careful consideration, not only to avoid making the finished rice sticky, but also to give just sufficient lustre to satisfy the eye.

Not every variety of rice is improved in appearance by facing, but this process does in effect protect the highly milled surface of the grain and preserve it from deterioration.

With good milling, however, it is possible to impart to suitable rices a natural finish which cannot be approached as regards excellence or, indeed, beauty, by any artificial coating or glazing process.

13. **Elevating and Conveying Machinery.** Although the transference of the grain from one machine to another is accomplished in certain cases by gravity, particularly in large mills, the employment of mechanical handling plant is unavoidable.

Even though machinery may be arranged so as to get the full benefit of gravity runs, the grain must now and then be re-elevated to supply other machines. Again, the grain may have to be transported on the level from one point to another of a large mill. In order to do this, two classes of conveyors and a standard type of belt and bucket elevator are employed.

For bringing grain into store, or for conveying it in bulk from store to cleaning plant, band conveyors are usually employed, consisting of endless belts, often several hundred feet in length.

These bands are frequently made of cotton and rubber, and in any case are usually rubber-faced ; they are supported at frequent intervals by idle rollers, and are provided at one end with tension carriages to take up slack when the belt stretches. Outside the mill building they are most conveniently operated by electric motor, and their capacity for handling grain in bulk is too well known to require further comment. If running outside, they may be protected from the weather by a light wooden roof or, as is sometimes done in large installations, placed underground in covered trenches.

Within the mill, and for horizontal transport over relatively short distances, either a small belt conveyor or some form of screw conveyor is commonly used.

Spiral conveyors are usually employed for the conveyance of finer material such as broken grain and dust, meal or bran, and husk ; such conveyors should be contained in steel troughs and totally enclosed to prevent the escape of the material.

Elevators are employed for the vertical transport of grain and by-products from one floor to another, and are of the well-known type common to all grain mills. The belts are preferably of strong woven cotton, to which pressed steel buckets are attached at intervals. At the bottom of the elevator—the boot, as it is termed—arrangements are provided for stretching the belt, to make allowance for the inevitable extension which occurs in working. These elevators are usually encased in light sheet steel trunks, to minimize the risk of fire.

We have still one important aspect of rice preparation to consider, although it does not affect the milling processes nor yet the machines used in carrying these out. We have already referred to the parboiling of rice, and will now briefly describe the manner in which it is done.

14. **The Parboiling of Rice.** Whatever may have been the origin of this particular process, and opinions differ considerably on the point, it is certain that rice has been treated in this manner for many generations, particularly in India.

There are actually three different pre-milling processes of somewhat similar nature : in one, the grain is simply sprinkled with hot water and allowed to dry ; in another, it is steeped in cold water for twenty-four hours and then dried in the sun. The third is the true parboiling process which we are about to describe.

First, the grain is deposited in tanks—usually of native brick or concrete—where it is submerged in water and kept at a temperature of round about 100° F. for a period ranging—according to grain, locality, climate, and other conditions—from twenty to thirty hours. After this protracted steeping, the water is run off ; the sodden grain is withdrawn, and placed in cylindrical vessels of sheet metal into which steam, at atmospheric pressure or a little over, is admitted in sufficient volume to permit of each individual grain being acted upon. This, which is the real parboiling part of the process, is only continued for a few minutes until the mass of grain is heated through, when the steam supply is shut off and the cylindrical vessels are emptied by suitable means. From the parboiling vessels, the wet grain is now conveyed to an adjacent drying ground which consists of a sun-baked earth, native brick, or cement, floor of considerable area, over which the wet grain is spread by women and children. Here it is allowed to lie, exposed to the direct rays of a tropical sun, being periodically turned over by rakes or by the simple process of many small bare feet walking backwards and forwards among it until, after the lapse of perhaps a couple of days, it is sufficiently dry to be milled.

Where this system is in vogue, particularly in more northerly latitudes, it may be necessary to rake the drying grain together into heaps before sunset, and to cover it over for protection from dew or excessive cold during the night. After the sun has risen again, the grain is once more spread over the ground, under the hot rays of the sun, and the process is continued until the requisite degree of dryness is attained.

When delivered tô the mill, the grain is subjected to the usual processes already described, but it requires less preliminary cleaning, and it shells with the utmost ease, so that very little unshelled grain comes back to the hullers; it is also rendered much tougher, so that much less rice is broken in the milling processes.

One has only to take a run by motor-car round the outskirts of a city like Calcutta, Madras, or Colombo, to see many of these parboiling and drying plants in operation. They provide the requisite grain for numerous small though mechanically equipped mills, which all contribute their share to the enormous volume of some 30,000,000 tons of cleaned rice for which India is responsible, on the average, each year.

It will be obvious that the preparation of parboiled rice can only in the dry season be effectively carried out, if sun-drying has to be depended on. For this reason one finds, in districts where alternative raw material is available, that small rice mills are combined with vegetable oil expressing plants, with native sugar mills, or with small saw mills, so that during the rains the power plant and buildings are not idle but are able to contribute towards standing charges. The extended milling of parboiled rice and its preparation on a large scale have brought about a relatively recent development of considerable importance, namely, the design and construction of artificial dryers, by the adoption of which the miller may be relieved from anxiety due to the incidence of cold or rainfall.

The amount of time, ingenuity, and money, expended during the last fifteen years on the design and construction of experimental drying plant, has been considerable. The problem is not so simple as might appear at first sight.

It is one of the chief objects of the miller to produce the maximum possible percentage of whole, well-finished, and uniform grains in his final product; and unless great care is exercised in drying wet paddy there is considerable risk of cracking the kernels within the outer husk, thus lowering the market value of the finished rice.

Such cracking may result from overheating during a short period of time, or through over-prolonged drying without excessive heat. On the other hand, unless the grain is dried uniformly throughout, the finished sample may be anything but satisfactory. Moreover, apart from the danger of cracking through overheating, there is the risk of serious discoloration of the grain through unduly prolonged contact with hot surfaces.

The old native system of parboiling pans, though simple, is susceptible of improvement as it involves a not inconsiderable amount of labour and loss. There is room for the production of more effective plant at a price which will bring it within easier reach of the small native miller.

The drying plant itself may be of varied construction : it may consist of vertical tubes or pipe sections through which the wet grain is allowed to fall, coming into contact on its downward path with a counter-current of warm air heated by steam or by direct firing ; and in certain designs the warm grain is thereafter subjected to a current of cool, dry air. There are various ways in which this system is applied, and different devices have been adopted to reduce the amount of heat required to effect drying. A certain amount of heat has to be expended in order to dispel a certain quantity of moisture ; and the moisture added by the older steeping and parboiling, or cooking, methods may be as much as 45 to 50 per cent, by weight, of the grain in its natural state. Other things being equal, a process which will sufficiently "cook" the paddy without necessitating the absorption of so much added moisture, is worthy of consideration. Improvements have already been made in this direction, and other designs, having the same end in view, are being developed.

Again, we have the hot-plate system in which the damp grain is simply laid on metal plates heated from below by steam pipes or by suitably regulated direct firing. Experiments have been carried out involving the employment of slowly revolving drums inside which the wet grain is trundled, suitable arrangements being made for heating the drum and for evacuating the vapour given off.

At the present time, no artificial system of drying yet produced can compare in efficiency with natural sun-drying ; but sun-drying is impossible for four or five months in the year in many of the rice areas principally concerned. The systems so far put into operation are relatively costly ; but as further experience is gained one may confidently look for better results from a commercial as well as from a technical point of view.

The difficulty and cost of securing and preparing adequate drying grounds are considerable ; and the nearer such installations are established to populous towns, the more is the cost increased, until it may become prohibitive. It will thus be realised how important it is to find a satisfactory commercial solution of the problem of drying wet paddy.

CHAPTER X

POWER PLANT AND AUXILIARY SERVICES

ANY form of prime mover or secondary power transmitter may be used for operating the machinery of a rice mill, ranging from the manual labour of the simple native, up to high-powered engines embodying all the latest improvements, which one finds in modern large mills.

For many centuries the native cultivator was his own prime mover. Later, as simple and elementary forms of machinery were employed, the inevitable bullock was pressed into service for operating millstones through some simple form of gearing.

As improved machinery was introduced, so also, were better methods of driving that machinery sought after ; and water-wheels, or simple steam engines and boilers, were installed.

Nowadays, in some of the small native mills, electricity is the source of energy where a suitable supply is available ; and, where it is not, oil engines, gas engines, and the latest types of modern steam engines are installed. For what are usually termed small mills, dealing with anything up to 30 or 40 cwt. of paddy an hour, the electric motor is extremely convenient, failing which the paraffin or lighter crude oil engine is both economical and convenient, as such oils are now universally obtainable. The chief source of power, however, is the husk of the rice itself, as this is always available and is not readily utilizable for any other purpose. In primitive milling a good deal of meal and broken rice is mixed up with the husk, the separation of which, under such conditions, would be a difficult operation ; but under modern methods, even in quite small installations, the husk is automatically separated from the true grain and is blown or aspirated into a suitable receptacle from which it can be withdrawn and used as fuel.

The calorific value of husk is not high in itself compared even with ordinary factory coal, and special provision must be made for burning it.

The consumption of husk by weight may be as much as, and even more than, three times that of coal in order to give the same evaporation of steam. It is therefore usual to employ an independent furnace, that is to say, external to and independent of the boiler to be fired—by which means a much greater volume of husk can be burned, the flame and hot gases passing through short tubes connecting the furnace with the boiler.

Husk furnaces are usually of the step-grate or venetian type, consisting of a series of firebars placed one above another in the form of steps, with ample space between to permit the admission of plenty of air to support combustion. The husk is discharged from a hopper over the stepped bars, and, the fire once started, and the shower of husk ignited, it burns with intense heat. The whole is contained in a fire-brick casing, the flames passing into the boiler, and the burnt husk falling to the bottom of the furnace, whence it is either raked out or automatically removed by a constant stream of water.

Similar furnaces are constructed to burn wood refuse as fuel, but, except in the smallest mills, the husk given off in the milling process is sufficient to generate steam to operate an engine powerful enough to drive the mill.

For this reason practically every large mill engaged in treating rice through all its stages, including hulling or shelling, is operated by steam, as the only cost for fuel is that of collecting and conveying it to the furnace ; like all other processes in a large modern mill, this is done automatically.

This is, moreover, the ideal method for disposing of the husk, which otherwise becomes a burden. It is collected and stored, and any surplus not required by the mill producing it, can be sold as fuel to other industrial undertakings.

During recent years the husk has been employed for the generation of gas to actuate gas engines. So far, no large installations have been put into operation with rice husk gas ; but there is much to be said in favour of this combination, particularly where the water supply for steam-raising is either insufficient or bad.

Careful and prolonged tests have been carried out, and have shown excellent results in the case of small installations ; and further useful developments on these lines may be anticipated.

Where white rice milling only is undertaken, in European or other ports, and therefore, no husk is available, the source of power may be whatever is most convenient ; if a reliable supply of electricity is available at a favourable rate, the adoption of electrical group-driving has much to recommend it, although the modern economical steam engine still holds its own.

In those Eastern mills where the parboiling process is in operation, steam is essential for cooking and is also convenient for drying if artificial dryers are employed ; in such cases it may as well be utilized for power purposes also.

The selection of a suitable boiler is largely governed by the nature of the feed-water available ; tropical water supplies are often inadequate or contain large quantities of matter in suspension. For this reason, and although tubular and water-tube boilers are not infrequently installed, the ordinary single or double-flued factory boiler has yet to find a serious rival.

We can hardly leave the subject of machinery and power plant without some reference, however brief, to the question of power transmission in the mill building. Every big mill or factory owner is aware that a regrettable proportion of the total power generated by his prime mover, is absorbed in friction losses. In a cereal mill where the presence of fine light dust is inevitable, attention must be given to the design of the shafting for driving the different machines, and of the bearings in which that shafting is carried. In the case of large mills operated in tropical countries by native labour, the use of self-oiling enclosed bearings is imperative, while in certain cases roller or ball-bearings are desirable. Anything which will reduce risk through inattention or lack of lubrication is worthy of consideration, and an otherwise excellent mill may be spoiled by lack of attention to the important details of power transmission.

The equipment of a modern rice mill includes electric lighting plant, fire service, and other auxiliary machinery. Most mills of large size in the East have their own workshops, where ordinary running repairs can be quickly executed.

Although, in the off-season, many of these large installations may be idle, or practically so, for weeks at a time, it is a case of strenuous day and night work for months on end when the milling season commences. In preparation for this all the machinery must be overhauled, tuned up, and generally brought to the highest pitch of condition as, once the new crop is available, any stoppage for adjustment or repairs may mean serious loss.

The provision of an adequate fire service is of utmost importance.

Although great improvements have been effected in the construction of individual machines as well as in the method of distribution throughout the mill, and have resulted in the avoidance of anything but the finest and lightest meal dust, the complete collection and elimination of this is not always possible. Wherever there is an accumulation of fine dust, especially when operation is continuous, night and day, and in a tropical country where native labour is employed, there also will fire risks occur. It is the aim of the first-class designer to reduce such risks to a minimum, and at the same time to make provision for the best fire extinguishing service possible under the circumstances. The installation of automatic sprinklers is recommended in the case of larger mills.

CHAPTER XI

BUILDINGS, VENTILATION, LIGHTING, AND STORAGE

It is only necessary to make brief mention of these in connection with rice milling, because such buildings are similar to those required for most large manufacturing concerns. While, in America and Europe, buildings for the accommodation of rice machinery are usually constructed of stone or brick, it is otherwise in the East. At one time even the large mills were constructed of brick ; but, except inland, or in cases where the cost of steel-framed buildings may be unduly high in comparison with native brick buildings, the tendency is now to adopt steel construction with galvanized corrugated iron sides and roofs.

One used to see timber-framed buildings constructed of most substantial posts and cross-beams of teak or other tropical wood, with sides and roofs of corrugated iron, but the price of timber now is against this type of construction.

In certain cases buildings of ferro-concrete have been projected and some have been built, but the weight of such buildings is considerable ; it often happens that the mill is placed on practically water-logged land alongside a creek, and difficulty is experienced with foundations. Many large mills are to all intents and purposes carried on a concrete " raft" generously supported by heavy wood piling, the mill, engine-room, and boiler-house requiring such support to ensure that correct alignment of machinery is maintained.

Where a considerable amount of machinery is devoted to grading and separating rice, and such machinery is in constant reciprocating operation, there is considerable tendency to vibration. For this reason it is important that buildings should be designed to reduce the effects of such vibration, to a minimum.

Ventilation. In all buildings—and in large mills these may be four or five storeys high—the provision of ample window spaces fitted with shutters or glazing which can be quickly closed, as well as of large ventilators, is important. A certain amount of dust will find its way out of inspection doors and will settle on the surrounding machinery, some of which may be located in the less accessible or less frequently visited parts of the building, and it is important to guard against the risk of fire due to overheated bearings.

The heat generated by certain machines during the milling process is considerable, so that, from every point of view, ample ventilation and light are greatly to be desired.

The storage magazines, or " go-downs," as they are termed throughout the East, may be of simple construction ; they have no live weight to carry and no machinery in operation beyond, perhaps, a slowly moving conveyor or elevator for handling the grain.

Here again, however, ventilation is of great importance ; wherever fresh grain is stored, especially if it be in any degree damp, there is liability to heating, accompanied, sometimes, by an outbreak of fire which may not be readily detected if the material merely smoulders. Go-downs containing finished products must be equally well ventilated ; in all cases such ventilation must be so arranged as to minimize the possibility of rain leakage ; which is obviously of great importance in a tropical country subject to severe rainstorms.

The adequate construction of stores for finished products is the more important as it is in these that rice is liable to damage by weevil and by vermin, especially if it has to be stored for any length of time prior to shipment. The amount of damage done to valuable grain in this way may be most serious ; care should be exercised in the design and construction, and thereafter, in the periodic examination and cleansing, of these buildings.

Lighting. Just as mill buildings require to be provided with ample light and air during the day time, so also, it is essential that the modern mill, its go-downs, and "compound" or yard, be adequately equipped with artificial lighting when milling is carried on all night. It is desirable that the different floors and, indeed, the surroundings of the principal machines, should be adequately lighted, and that wall plugs be fitted to allow of special examination from time to time when repairs or refits are being carried out.

It is also desirable that one or, preferably, duplicate, independent lighting sets should be installed in a separate building if possible, so that, in the event of breakdown, fire in the engine-room, or during regular stoppages for overhaul, the lighting of the premises may be efficiently maintained.

The utmost attention should be paid to electric wiring, particularly in tropical countries where insect life abounds and where native labour is employed; failure to take the most obvious precautions in fitting up such wiring, as well as in examining its condition periodically, has resulted in disastrous fires.

While on the subject of storage, attention may be called to two interesting features of the Eastern rice trade. The first of these relates to the storage of grain for the large mills in Siam, Indo-China, and other important centres where the rice is stored in go-downs under the control of officials of the big European banks, a considerable part of whose business consists in financing those engaged in the rice trade against the security of the grain so stored. These go-downs are locked up, and the initials of the bank in whose name the stocks are held, are painted in large letters across the doors. The withdrawal of grain is under the control of a representative of the bank in question. As these mills are designed to turn out daily anything from 300 to 1,000 tons of finished rice to a mill (according to size), it will be seen that considerable financial interests are involved.

The other matter to which we would direct attention, is the admirable system of inspection and storage adopted in Japan.

For centuries during the old feudal days it was customary to pay taxes in rice, and great care was exercised by the nobles to ensure that only rice of the finest quality was delivered.

After the Revolution in 1868, however, the Japanese Government introduced the system of paying taxes in cash, with the perhaps inevitable result that the producer applied his mind more closely to the matter of quantity rather than quality, which rapidly deteriorated in consequence. The establishment of rice exchanges unfortunately acted in the same direction, as dealers were anxious to get as much rice as possible through their hands. Markets became flooded with bales of immature and inferior grain, often adulterated and otherwise tampered with, until the well-deserved reputation which Japanese rice had earned was entirely lost. Not only so, but such a thing as a standard bale of rice ceased, in many districts, to exist ; and, what with one thing and another, it is not surprising that matters came to such a pass as to make the re-imposition of some form of control imperative.

Between 1880 and 1890 various attempts were made to restore the prestige which Japan rice had always enjoyed, and gradually the rice dealers themselves came to realise the error of their ways and the disastrous results of their former policy. By degrees, and in the various Prefectures where the cultivation of this cereal predominated, guilds of rice producers, rice dealers, and rice shippers were formed. The Prefectural governors issued appeals to all interested to come forward and join the movement, with the result that improvements were soon effected, abuses abolished, and a spirit of emulation was aroused. General regulations for the inspection of rice were promulgated and reforms instituted, which together resulted in the attainment of a standard of perfection which is not excelled—if it is attained—in any other country in the world.

Storage depôts and inspection offices have been set up not only in each Prefecture but in a number of centres in each Prefecture ; awards are made to those cultivators whose rice conforms most closely to the regulations laid down, and similarly, fines or penalties are exacted from those whose rice falls short of the standard of excellence which it is the aim of all to attain.

The regulations apply, with suitable modifications, to paddy as well as to milled rice, and not only so, but the rice bales themselves, i.e. the rice straw wrappings in which the grain is made up, have to conform to a specific and rigid standard. Time and space alike prohibit a more extended reference to this particular aspect of our subject, but the official reports of the various Prefectures, published in English, are most illuminating reading to those interested. It may be added that, alike in Japan, Korea, and Formosa, agricultural colleges and experimental stations are established in which the most valuable research work is carried out, with the result that Japan seed has spread all over the world and is now cultivated in many countries many miles from its original home.

CHAPTER XII

THE ENEMIES OF RICE, AND METHODS OF COMBATING THEM

HAVING dealt in the foregoing chapters with the general question of cultivating, milling, and storing rice, we may perhaps usefully give somewhat closer attention to a most important matter which has been touched on at various points in the preceding pages.

Through all stages of its growth, as well as in its final condition as a commercial commodity, rice is liable to attack at many points, and perhaps its principal enemies are the most inconspicuous.

First of all, we must recollect that in tropical countries where rice grows most profusely and naturally—that is to say, in the absence of any highly developed agricultural system—the early growing period synchronizes with the early rains, and follows on a long spell of heat and drought. To many animals which do not prey on their fellows but which depend rather on vegetable foods, the combination of refreshing rains and succulent tender rice shoots constitutes a temptation too strong to resist.

Elephant, deer, boar, and the ubiquitous monkey come down to the new paddy fields with the determined intention of securing a food which is particularly attractive to them. It is necessary in such cases to make provision for guarding the fields, and primitive watch towers are often erected from which the cultivator can watch over his precious treasure, the destruction of which would mean not only heavy financial loss, but famine and sickness as well.

Serious as the depredations of these animals may be, the aggressors are at least easily discovered and relatively easily warned off.

The more subtle and extremely difficult enemies to overcome are two-fold ; first, the various insects to which the young and growing rice, and indeed, the mature but still unharvested grain also, offer such attraction ; and, in the second place, the parasitic fungi which so readily infest the grain at various stages of its growth, as well as at various points in its structure.

It may be stated without exaggeration that losses due to these causes alone amount, in certain districts, to as much as 50 per cent and more of the total crop. What the American agriculturist terms the rice bug (*Leptocorisa acuta*), one of the most serious and inveterate enemies of rice, together with its life history and depredations, is vividly described in two or three numbers of the *Philippine Agricultural Review*—perhaps best of all in the Rice Number, Vol. XIV, No. 1, for 1921. It is also dealt with by Professor Maxwell-Lefroy in the *Memoirs of the Department of Agriculture in India*, as well as by other writers ; the reader, if interested in this aspect of our subject, is recommended to peruse those articles.

This creature feeds on the rice panicles, or heads, when formed, and is so attracted by this cereal that, although he will feed for long periods on other grasses, he will desert these as soon as his favourite food is ripe for his attention.

It is injurious in all stages after hatching from the egg, but its chief activity consists in boring into the forming grains, during what is known as the " heading " period, and eating out the endosperm or kernel, with the result that, although the husk may attain maturity and present the appearance of a full grain, it is in fact empty.

Another somewhat similar operator is the stink bug (*Oebalus pugnax*), which in like manner punctures the kernel in the early or so-called " milk " stage, with the result that the kernel shrivels up and becomes valueless. If it is punctured at a later stage, the damage may not appear so serious, but the grain may crack in milling or be discoloured and otherwise damaged by the development of fungi within the puncture.

In the southern (rice growing) states of North America and other countries as well, the rice water weevil (*Lissorhoptrus simplex*) does great damage and is regarded there as the most injurious insect enemy of growing rice. As soon as irrigation water is turned on, the adult appears, moving freely in water, and attacking the leaves of the young plants. Not only so, but the larvae feed on the roots and, between the two, the plant suffers severely—more, indeed, from the larvae than from the weevil itself,—with the result that, though the plant may not be destroyed, its growth is stunted and the crop ripens unevenly.

Caterpillars also constitute a serious menace, the tender young shoots again forming the object of their attack.

A certain moth (*Chilo plejadellus*) is another enemy ; its larva chooses the stem of the rice, preferably where the plant grows somewhat thickly ; feeding occurs inside the stem whereby the plant is weakened, does not flower, and therefore does not develop grain.

The methods adopted for checking these various attacks are many, interesting, and laborious. To mention just one or two, the rice bug is captured by a drag-net being drawn through and over the growing plants before the insect is old enough to develop wings and fly about. Nature also assists in that the larvae of the tiger beetle regard the rice bug as a particular delicacy and feed on it ; while, finally, a certain egg parasite has selected the bug as its prey and aids the farmer in attacking and destroying this particular pest.

As far as the water weevil is concerned, the only way to minimize the loss, if not to avoid it, is to drain the fields while the larvae are still young and to keep them dry, so long as the plants do not suffer, until the larvae die off.

In addition to insects, rice suffers from fungoid growths such as " blast " or " rotten-neck," which attacks the plant at the juncture of leaf blade and sheath, as well as at the top of the stem where the head of grain joins it, with the result that the plant dries up and the grains do not fill. If the disease attacks the neck after the grain has developed, the neck has not sufficient strength to carry the head, which then breaks off. Other diseases such as " green smut " and " black smut " attack the actual grains, and while these diseases may not be serious in some countries they are undoubtedly so in others.

It would appear that the only way to combat these is by careful seed selection, and this for two reasons. In the first place, infected seed can be detected and eliminated by the methods already described under " seed selection," thus obviating the sowing of such seed. In the second place, it is an established fact that certain rice varieties are much more susceptible than others, to certain diseases ; and, by experimental methods applied at agricultural research stations, it is now possible to determine, within reasonably accurate limits, what varieties will resist this or that parasite and what will not.

In this connection it is of interest to observe that most bearded varieties of rice do not suffer from the attack of the rice bug. Moreover, such varieties are more or less immune from attack by the rice bird, or bobolink, of the United States, which feeds freely on other varieties when opportunity offers ; bearded varieties are not, as a rule, such a profitable crop as the non-bearded grains, and are therefore not willingly cultivated.

One other serious enemy of this cereal is weed, and a very serious enemy it is.

The conditions under which rice is cultivated favour the development and growth of weed also. We have referred to this before, but emphasize the importance of seeing that seed rice is as pure and free from foreign seed as the most careful selection, separation, and winnowing will make it ; that the surrounding banks of the paddy fields are kept free of weed, and that transplanted rice is set out in such a way as to permit of cleaning between the rows. Further, where threshing machinery is hired out from one farm to another, it must be in a thoroughly clean condition.

In the rice fields of the United States of America red-grained varieties are looked on as weeds and are treated accordingly ; if this rule were applied to Oriental rices, the yield would be materially decreased,as many samples of hulled rices, taken at random from various areas, show a fair proportion—some, here and there, an overwhelming proportion—of red grains. Considered as a food, red rice is as good as white, but, from the commercial standpoint, the red-skinned rice is more difficult, or at least more expensive, to mill into pearled white rice. It is stated that the American farmer, recognizing the red variety by its looser and slightly drooping head carrying relatively few grains compared with plants of selected white rices, pulls up the former and carts them from the field.

In highly developed cultivation this may be a commercial proposition; but not where the staple or only food of millions is concerned.

1. **The Presence of Weevil in, and its Destruction and Removal from, Stored Rice.** No review of the matter contained in this section of our handbook would be complete without some reference to a pest which sometimes causes serious loss, and often at least involves considerable expense, in connection with the storage of finished unglazed white rice.

We refer to the presence of the rice weevil, or *Calandra oryzae,* which occurs in many bulk samples of tropical white-milled rices. This insect belongs to a class of small beetles and is a voracious little creature about 4 mm., or, say, a little over $\frac{1}{8}$ in. in length, dull brown in colour, and provided with a strong beak bearing a pair of mandibles. Said to have originated in India, it is unfortunately met with now in practically every rice-growing or rice-storing country in the world. While it is chiefly objectionable in relation to milled rice, it also attacks unshelled grain; the larvae have strong jaws and easily make their way through the husk or shell of most vegetable products.

The female bores a small hole in the grain and, after turning round, deposits an egg therein, makes her way out, and seals the opening. When the grub hatches out, it feeds on the kernel, and after attaining maturity the insect also makes its way out of the grain; this small hole can sometimes be observed in individual paddy grains occurring in rice samples in this country.

It is, however, the persistence of weevil in the finished rice, ready for human consumption, which causes so much annoyance and loss, just, in fact, as it has done in stored wheat, where such serious losses have occurred as to call for special Government attention.

Samples of white rices coming home to Europe often exhibit, or may later on develop, web-like growths which turn into grubs and ultimately into the full-sized weevil, and rice infested in this manner is quite unfit for human consumption.

Prevention is ever better than cure, and when white-milled rice has to be stored, no pains should be spared to see that storehouses or go-downs are kept in scrupulously clean condition ; cracks in flooring and walls and discharge spouts from elevators should be thoroughly swept out and, where possible, washed down with a solution of caustic soda. The store should be well ventilated and secured as far as possible from the intrusion of damp ; it should also be well lighted.

The presence of weevil in white rice is accentuated by the close proximity of lower grade broken rice, and particularly of rice bran which should be excluded, or at least kept as far from the higher grade product as possible.

Artificial coating or facing of the rice does undoubtedly either prevent or greatly tend to prevent weevil, and samples of glazed rice from overseas, kept in this country for several years, have shown no sign of this pest. On the other hand, the author, when visiting some milling friends on the Continent, wished to see a certain sample of white but unfaced rice which had just arrived from the East ; he was presented with a glass jar which, on being opened, was so thoroughly and completely alive that the whole thing had to be consigned to the fire.

There are two or three ways of dealing with weevilly rice in bulk, and these will be briefly described.

2. **Mechanically.** Where white rice is stored in a mill go-down and is to be freed from weevil before shipment, this can be satisfactorily accomplished by re-passing the rice over a series of sieves which effectively remove

webby growths and maggots; after leaving the sieves, the cleaned grain should be passed through aspirators, which will take out any fully developed weevil and also eliminate a proportion, at least, of light grains into which these insects may have eaten. Should the amount of head rice so attacked be considerable, the aspirator may not be able to remove anything like the whole or even a large proportion of it, but this can be effected by utilizing the paddy separator described on page 75 for separating shelled from unshelled grain—in the case under review the machine dealing again with grains of somewhat similar size and shape, but, owing to the attacks of the weevil, of different weight. It is not as a rule necessary to fit up any special machines for this purpose as rice does not tend to become infected during the actual milling season, but rather when that period is finished and existing machinery is available. It need scarcely be emphasized that all webs, grubs, and insects must be carefully collected and burnt to prevent subsequent infection, and the machinery used must be scrupulously cleaned before being again employed in routine milling.

One frequent source of trouble is the use of old gunny bags which may have been infected already from other sources, and which are stacked in or near the white rice go-down for transport of the finished material. It is desirable to pass these through a bag-cleaning machine, consisting usually of an hexagonal sparred drum capable of containing from 50 to 100 sacks, which are introduced through a suitable hinged door in one of the six faces. The drum is supported and revolved on gudgeons by means of any suitable gearing, and, as the bags are tumbled about for some ten minutes, the dust, web, and weevil are shaken and beaten out and escape through the sparred faces and sides of the drum. It is obviously desirable to conduct this operation within a space well partitioned off from the rest of the mill or go-downs, and having a floor which can be swept absolutely clean and then swabbed down with some suitable insecticide.

3. **Chemical.** This method of de-weeviling is more applicable to places in which finished grain is stored for periodic distribution and in which it is possible that some at least may remain for a considerable time. It has also been applied to mills, but owing to the unavoidable presence of many doors, windows, and ventilators, the destruction of weevil in this way is cumbersome and inclined to be costly; besides which, fumigation with poisonous gases may be attended with considerable risk, especially in the case of native staff.

Two forms of fumigation are employed, either with hydrocyanic vapour or with carbon bisulphide. The first method is carried out by disposing stone or earthenware jars of three or four gallons capacity at suitable points in the building to be disinfected. A mixture of water and sulphuric acid, in suitable proportions, is run into each jar, and when all is in readiness, and every possible door, window, and ventilator is closed, the operator drops a previously prepared packet of sodium cyanide into each jar and retreats as hastily as possible. The gas liberated is extremely poisonous, and even one full inhalation in an unventilated room may be fatal.

The building should remain sealed for at least eight hours after the cyanide is dropped into the jars, and it need hardly be said that, after the operation is completed, all ventilators and windows must be re-opened *from the outside,* and kept open for at least an hour or two before any person is allowed to enter the building. About 1 lb. of cyanide to each 1,200 cub. ft. of space is an average allowance, but sufficient emphasis cannot be laid on the necessity for exercising the utmost care in preparing for this form of fumigation, which should not be attempted by inexpert or uneducated persons. Indeed, so insidious and rapid is the action of this poison that its use has been seriously propounded in America as an alternative to electrocution as a form of capital punishment.

Fumigation with carbon bisulphide is simple, relatively inexpensive, and fairly effective, but the vapour given off is heavier than air and is, moreover, extremely inflammable, so that no naked light whatsoever may be used in connection with the preparation of this operation. Opinions appear to differ considerably as to the amount necessary to effect disinfection, one authority giving 4lb. of carbon bisulphide per 1,000 cub. ft., or 1lb. for every 35 bushels of grain; whereas another gives 1lb. per 1,000 cub. ft. or per 100 bushels. Much naturally depends on the construction of the building and on its air-tightness. The bisulphide is placed in open trays disposed as may be most convenient, and the building should be kept closed for about forty to forty-eight hours. When this system is to be applied to stored *paddy* or unhusked rice, of which a certain amount may be required for seed, fumigation should not be extended over thirty to thirty-five hours, as germination may be adversely effected by more prolonged exposure to the gas.

Formaldehyde has been tried in this connection, but it is not an effective insecticide and, moreover, it has a detrimental effect on the surface of the finished rice, considerably lowering its market value.

4. **Heating.** Extensive tests of the destruction of insect life by heat have been carried out in some of the large rice mills in the southern United States, and the results are extremely interesting as well as satisfactory. An available heating system, however, is by no means

common and is altogether absent in tropical mills and storages, so that the system is not easy of application; and the cost of fitting up the necessary connections and heating appliances to a building not otherwise equipped therewith, would in many cases be prohibitive.

Against that, however, the period required for destruction by heat, without affecting the grain, can be so short—particularly in the case of stored rice—that the cost of installation may be relatively unimportant.

The volume and value of the grain to be treated, the extent of infection, and the construction and design of the store, are important factors which all go to determine the best method to be adopted in individual cases.

It should be borne in mind, however, that all these methods of treating infected rice have certain disadvantages, either economic, physical, or chemical, and, while effective, they should not be undertaken by any uninformed person.

It does not appear that the rice is adversely affected by any of the foregoing de-weeviling processes, at least, not so far as its food value is concerned, and, after all, the ultimate end of all good rice is to be eaten.

We will now proceed to consider rice from that point of view.

CHAPTER XIII

RICE AS A FOOD, AND UTILIZATION OF BY-PRODUCTS

It has been stated that this cereal is the staple food of more than half the population of the world, and, after considering the methods and processes by which it arrives at the stage where it is ready to be consumed, it is fitting to consider briefly what the food value of rice actually is.

It is nutritious, easily digested, easily prepared, and, of the utmost importance in the great countries of its origin, relatively cheap.

A single grain of rice is a wonderful storehouse containing protein, fat, starch, sugar, mineral and fibrous matter, and that valuable and relatively recently discovered, though elusive, quantity known as vitamin B.

In cataloguing all these possessions we are referring to hulled rice before it is milled, and we have already called attention in a general way to the lowering of food-value which invariably accompanies the milling of the grain, particularly up to the high standard demanded by European and American civilization. By removing the bran coating or cuticle in order to render the rice white—and in doing so we have also seen that the germ is removed simultaneously—part of the protein, fat, and mineral matter is eliminated, and a large proportion—in highly milled rices nearly all—of the vitamin B disappears.

Nevertheless, polished rice is still a valuable and nutritious food, being rich in starch, not unduly deficient in protein, and still containing traces of fat and mineral matter. The fuel value, so to speak, of most cereals does not markedly vary, although wheat contains more protein and fat than rice does, while the latter is richer in starch than the former.

The author has endeavoured to average out some of the many figures published in a number of agricultural bulletins, reviews, and other journals dealing with the constitution of rice.

Although these figures vary within considerable limits for what purport to be rices in similarly milled condition, an approximate result in respect of average quality milled rice—not highly polished and not glazed nor "coated"—may be represented as follows—

	Per cent.	
Moisture	12·8	
Proteins	7·1	
Fat	1·0	
Carbohydrates	77·9	
Fibre	0·4	
Ash	0·8	= 100·0

It is interesting to compare these figures with the average composition of Indian rice given on page 66 of *The Agricultural Ledger*, No. 5, for 1908-9 (Vegetable Products Series, No. 110), prepared by Mr. David Hooper, F.C.S., and published by the Indian Government, at Calcutta. This is a recognized work on the subject and contains a great deal of valuable information—the result of much patient research—on actual Indian varieties. The comparative figures given by Hooper are as follows—

	Per cent.	
Water	12·8	
Albuminoids	7·3	
Fat	0·6	
Starch	78·3	
Fibre	0·4	
Ash	0·6	= 100·0

Prof. A. H. Church, in his *Food Grains of India*, states that a large number of cleaned rice samples show results which accord wonderfully; in spite of great differences in appearance, as well as in the conditions under which the samples were grown, the nitrogenous constituent or albuminoids vary within narrow limits, say, roughly, not less than 7 and not more than 8 per cent.

The mineral constituents of such a sample are nitrogen in the form of nitrates or nitrites (predominating) round about 0·1, then phosphorus in the form of phosphoric acid, then potash, followed by magnesia, silica, and lime in very small quantities (0·03 to 0·025 per cent).

Analyses have also been compared of the meal or bran, which is the cuticle and germ of the rice removed in the whitening process, containing the most nourishing properties of the husked grain. The result in round figures is as follows—

	Per cent.	
Moisture	9·0	
Proteins	12·0	
Fat	13·0	
Carbohydrates	46·0	
Fibre	10·0	
Ash	10·0	= 100·0

The meal itself, of which the immediately foregoing figures show the constituents, represented 11·6 per cent of the whole husked rice; the reader, however, must take all these figures as approximate only, because the percentage of so-called "white" meal may vary greatly, not only according to whether a highly milled or an inferior grade of white rice is the product aimed at, but also according to the character of the grain itself. Some varieties have not only a rougher but apparently a tougher cuticle than others, and the latter will yield less meal than the former for an equal degree of surface finish.

Particulars of South Indian rices are recorded in the *Madras Agricultural Department's Year Book* for 1920–1, from which it will be seen that there was a marked variation in the food value of twenty-six varieties selected for examination ; in these the fat varied from 2·24 to 0·45 per cent ; crude protein, from 11·61 to 5·61—a remarkable difference ; carbohydrates, from 81·29 to 74·39 ; and fibre, from 0·58 to 0·11.

Reference has been made in preceding pages to red rice, and we have learned that this is looked on in the light of a weed in the United States, and certainly as a troublesome subject when milling high grades in the East. This same red rice is, nevertheless, cultivated and appreciated for its high food value in various districts, among which we will cite two cases only, parts of Madagascar and Upper Burma.

As Hooper puts it, the richness of any rice appears to be due not so much to the races of the plant or to the appearance of the grain, as to the cultivation ; and his conclusion is that grains of the finest composition are those from plants grown either in rich virgin soil or on land which has been liberally manured ; the latter is no doubt the cause of the excellent quality of Japanese rice.

Among various authorities consulted, the author has so far been unable to ascertain definitely why parboiled rice, subjected to the same degree of milling as an equal sample of " uncooked " white rice, should apparently retain the nourishing properties—or at least a fair proportion of these properties—which are removed when milling the latter quality, but all indications appear to substantiate the contention that it is so.

Reference has been made to the Oriental disease known as beri-beri or, as it is medically termed, polyneuritis. So great did the ravages of this disease become in certain countries that prolonged investigations were carried out in order to arrive in the first place at the cause, and in the second place at the remedy. It is a disease of considerable antiquity, which has been recorded in China from extremely remote times ; it has persisted through many centuries and has been marked by severe outbreaks in widely different parts of the world. A severe epidemic occurred sixty years ago in Brazil, and others, later on in Japan and Borneo ; but it is only within the last fifteen years or so that it has been successfully combated. Incidentally, the symptoms are loss of power, paralysis, no fever, and usually death through syncope.

The author has had the privilege, when in the Far East, of discussing this problem at first-hand with the medical officers of health at several ports. It was understood that the disease was most prevalent where natives lived at close quarters with one another, such as in police and military barracks, in prisons, or similar places. It was ascertained that where rice was eaten after being parboiled the disease did not occur, but that white milled rice, if not accompanied by a fish or legume diet, was sure to be associated with a more or less severe outbreak. The prevention of beri-beri in the Philippines, for example, has been very striking ; and the disease has practically been eliminated by reducing the rice ration from 20 to 16 oz. per day, by substituting considerably under-milled rice for that of a highly-milled quality, and also, by adding some convenient legume to the diet. In 1908 and 1909 there were in a certain area 600 cases annually : after the new diet regulations were put in force, there were only seven cases in seventeen months.

One has often seen the natives working about the large Eastern rice mills, taking a little of the meal (or pericarp and germ removed in the whitening process), mixing it with water, and drinking it, and no doubt such a concoction is an excellent specific against the disease.

In other cases a diet of par boiled rice has been insisted on with encouraging results. It would appear as though the prolonged steeping, softening the kernel, permits the nutritive qualities contained in the pericarp to be absorbed by the endosperm or true kernel ; it may be that the subsequent par boiling and sun (or artificial) drying process fix these qualities permanently in the kernel. Vitamin B, which is the nerve-recuperating vitamin, and which is present in rice meal, is soluble in water and withstands the boiling-point temperature, particularly during the brief period of par boiling (10 to 15 minutes) when the grain is closely packed in a closed retaining vessel.

We also referred to the question of the artificial glazing or facing of rice for high-class consumption ; it is fitting to note here that, while public health authorities do not impose any definite legal limit to the quantity of mineral matter employed in this process, it is generally accepted in this country that 0·5 per cent of added mineral matter is in no way injurious, and that quantity is quite sufficient—though often considerably exceeded outside these islands—to produce the desired result. If there is any suspicion that an undue amount of facing material has been added, it is open to the purchaser to take proceedings under the Food and Drugs Act, either on the ground that the article offered for sale is injurious to health, or that it is not of the nature, substance, and quality demanded.

As a matter of fact the whole of the glazing disappears while the rice is being cooked, and if those in charge of culinary operations will take the trouble to wash the rice before cooking there is not the least cause for anxiety.

The U.S. Government Food Inspection Decision, No. 67, issued in April, 1907, directs that faced rice shall be labelled in all cases with the name of the glazing material used, and many dealers add to this label the words : " Remove by washing before using."

Finally, a word on the cooking of rice is surely not out of place, because there are few things so unpleasant as the mass of sticky cereal with which one is too often presented if plain rice is served as food. Methods of cooking vary considerably. The Japanese adopt two methods : in both of these the white rice is washed and re-washed in clean water until the free starch is removed and the water remains clear ; *this is important and should always be done.* In the first method the washed rice is put into a small quantity of *boiling* water (see that it *is* boiling), and in the other case it is put into cold water and brought to the boil. When steam and froth escape from beneath the lid of the pot, the cooking is completed, but the grain is allowed to remain in the covered kettle for from half an hour to an hour longer, the steam causing the grains to swell and to separate freely from one another. The first method tends to produce drier, flakier rice. Salt should always be added, and cooking should be continued until no single grains remain which cannot be compressed easily between finger and thumb ; rice should not be stirred, but raised gently from time to time with a fork.

It is perhaps not out of place to indicate a recipe for a really satisfactory rice pudding ; a good rice pudding is a delightful dish, but a badly cooked one is fit only for transmission to the farmyard.

After the rice has been thoroughly washed as described above, take three level tablespoonfuls and add one quart of new milk ; mix with this one small tablespoonful of sugar and a pinch of salt, and bake in a slow oven for three hours. The author can bear testimony to the excellence of rice puddings cooked in this manner.

Experiments show that rice inevitably loses a certain proportion of its nutritive qualities during cooking, these passing into the water in which it is boiled.

For this reason this water should not be thrown away but rather retained and used in other culinary operations.

The United States Department of Agriculture, Cornell University, issue excellent pamphlets on Rice as Food and on Rice Cookery ; perusal of these will interest and repay those who wish to derive the maximum of benefit and satisfaction from this cereal.

As to the utilization of broken rice for consumption as food, we have already seen that broken " cargo " or " brown " rice is used for feeding cattle, pigs, and poultry, and that the straw itself is used as cattle feed in the East.

The meal and bran, as has been noted, are valuable foods though not humanly consumed as such by white races ; they are also used as component parts in the manufacture of the ordinary compound cattle feeding cakes.

As the germ of the grain is included in the meal, and as that germ is rich in oil, reasonable care must be taken that this by-product is not stored for too long a period, as it quickly goes rancid.

Apart from the manufacture of rice flour, the white broken rice is used for a variety of purposes, as, for example, in the brewing of beer, for which it finds a ready sale on the Continent ; for the manufacture of starch, for which it is well suited ; and for the production of alcohol.

In French Indo-China and other places there are large distilleries devoted to the manufacture of spirit and allied products on an extended scale, the raw material in all cases being broken rice.

The favourite Japanese spirit, " saké," as well as the even more potent Chinese " shemshu," is obtained by distillation from broken rice, which is also used for similar purposes in the Dutch East Indies.

Rice flour and ground rice are commodities familiar to all of us, and during the recent wheat shortage in France (1922-3) as well as in our own country during the Great War, the admixture of a definite proportion of rice flour to wheat flour was required in the manufacture of bread.

A certain amount of the very finest rice flour is used in making up medical prescriptions, in the preparation of patent foods, and for purposes of that sort.

We have seen that the straw is widely utilized in the East—perhaps more in Japan than elsewhere—for making hats and sandals, for thatching and bedding, for the manufacture of floor matting and screens, and, of course, for manure, but in its fresh state it is also used for cattle food.

Rice husks are unsuitable for any purpose other than fuel for which, however, they are admirably suited—either to be burned under furnaces to raise steam for industrial purposes or to be utilized in gas producers. They are of little value beyond this, although, when thoroughly dried, they have been successfully utilized as non-conducting or insulating material in the construction of cold storages and refrigerating chambers, and as packing material.

CHAPTER XIV

CONCLUSION

WITHIN the limits of a handbook of this description, which does not purport to do more than try to convey to its readers a general idea of the methods employed in cultivating the grain and preparing it for the market, there remains little which it is possible to add to such an admittedly superficial review.

Such a review might, however, be deemed incomplete if no reference, however brief, were made to the Rice Milling industry in this country. At one time English millers dealt with a considerable quantity of grain which is now, unfortunately, dealt with and milled almost exclusively on the Continent, principally in the large German and Dutch shipping ports.

To those to whom this particular aspect of the rice trade may appeal, we cannot do better than recommend perusal of the reports on rice, to which we have already referred, as contained in the Indian Trade Inquiry, published under the auspices of the Imperial Institute. During the War—to be exact, in August, 1916—the Secretary of State for India invited the Imperial Institute Committee for India to inquire into the possibility of extending the commercial use in this country of the principal raw products of India, including Food Grains.

It is to the report of that Committee to which we now refer, and it probably constitutes the most complete and comprehensive examination of the whole question ever undertaken.

Half a century ago there was a considerable number of rice mills, although these were not very large, in London and in Liverpool, but Ichabod has been written over most of these; there has not been for some years, and there is not at present, any outstanding indication that the industry is susceptible of marked revival in this country.

Such mills as still exist are of but small capacity compared with the large Continental mills, and they are devoted more to the manufacture of white rice by-products, such as grits and flour, than to what is broadly termed rice-milling proper.

There are doubtless ample and excellent reasons why this state of affairs should exist; but it is sad to reflect that, although the British Empire produces nearly 40 per cent of the world's total rice crop, and Great Britain consumes some 160,000 tons of finished rice per annum, an infinitesimally small proportion is dealt with by millers in this country, while nearly 40 per cent of it is imported from the Continent. It is not a question of greater skill or experience, either in the design and manufacture of suitable machinery, or in its operation when installed. We are simply faced with the fact that handling and general labour charges are lower in certain European ports than with us; and on this ground, and on it alone, British millers seem unable to compete with their Continental brethren.

Our review of the cultivation and treatment of rice is now finished, although one cannot venture to say that it is completed.

The subject is too big to be dealt with more fully in a handbook of this nature, but it is hoped that the general information given, and certain typical cases recorded, may repay the reader for his trouble.

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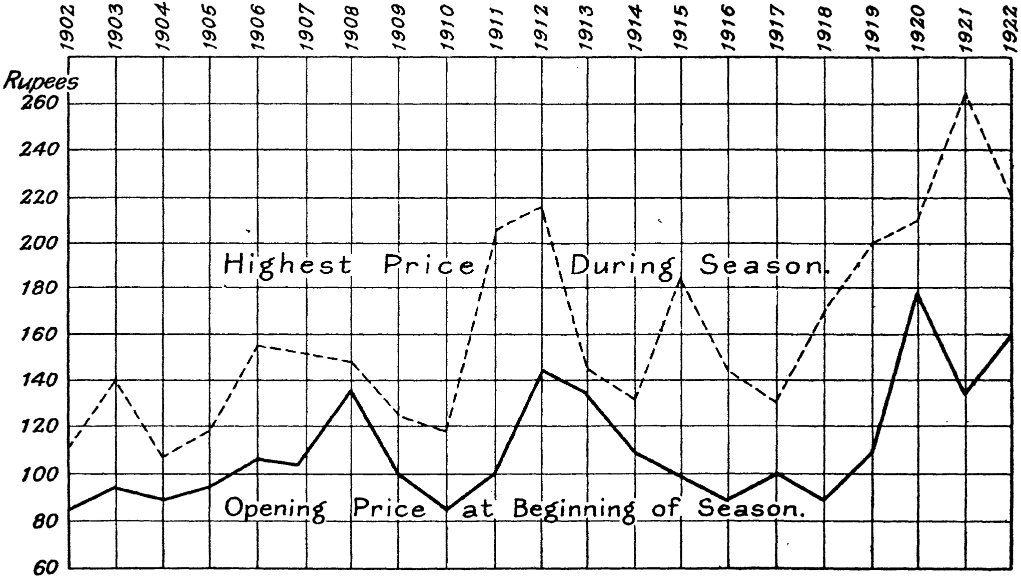

PRICES OF BURMA PADDY OVER TWENTY-ONE YEARS,
PRICE PER 100 BASKETS = 46 LBS.

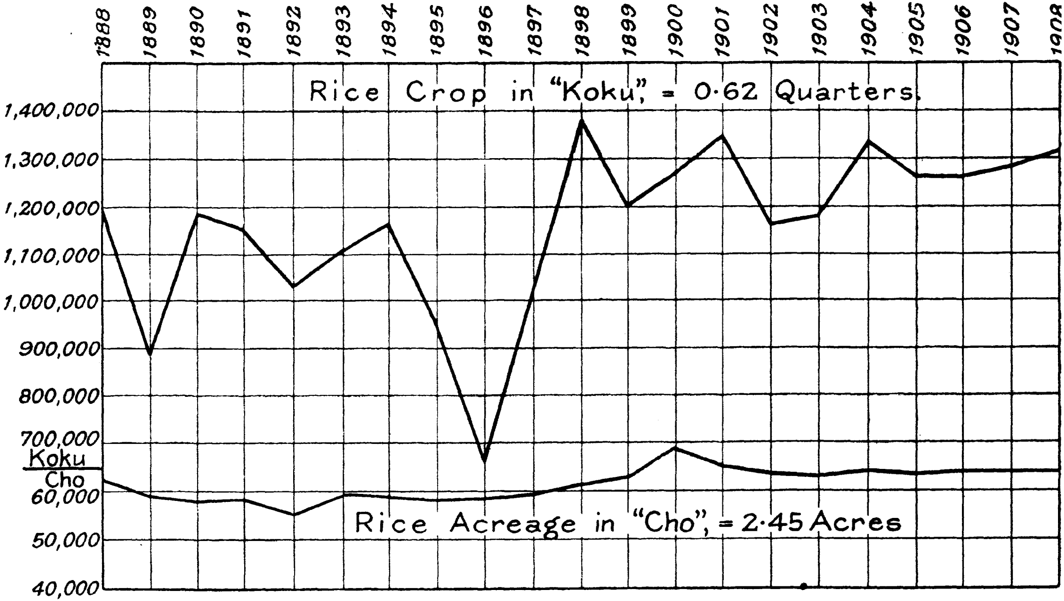

CHART SHOWING COMPARISON BETWEEN ACREAGE PRODUCTION PREPARED BY THE OMI PREFECTURAL RICE GUILD, JAPAN. OVER TWENTY-ONE YEARS.

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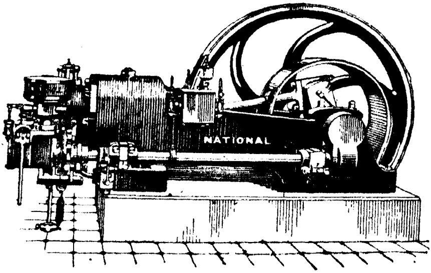

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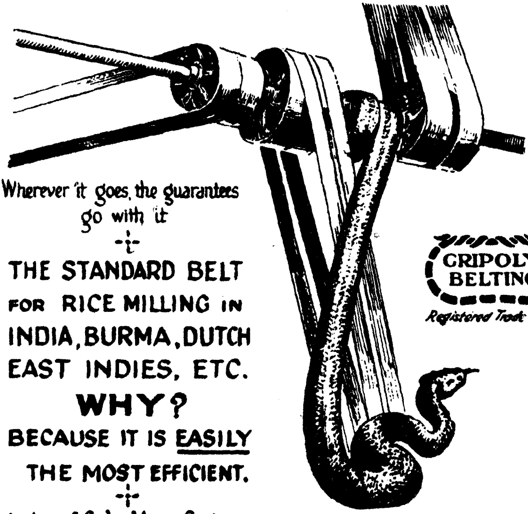

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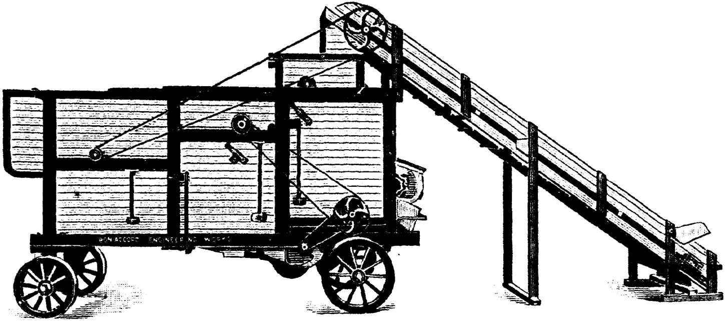

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